GREATER SAGE-GROUSE POPULATION TRENDS:
AN ANALYSIS OF LEK COUNT DATABASES 1965-2007

Provided To:

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From The

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Abstract - The decline of greater sage-grouse (*Centrocercus urophansianus*) populations has been a concern of naturalists and biologists since at least the early 1900s. More recently, this has prompted multiple petitions for listing under the Endangered Species Act and generated the need to update information on trends in populations over time. The primary approach to monitoring populations of greater sage-grouse has been to count males at traditional display sites (strutting grounds or leks) in the spring. The objective of this report is to analyze trends in male counts over three time frames (1965-2007, 1965-1985, 1986-2007) and at four geographic scales (range-wide, management zone, population, and state) relevant to conservation and management. We estimated trends in male counts using a set of linear mixed-effects models to test whether there was no trend, a linear trend (increasing or decreasing), or a quadratic trend in maximum male counts. We performed model selection using the Akaike Information Criterion (AIC). Our results generally suggest a long-term decline in greater sage-grouse maximum male counts with the greatest declines from the mid-1960s to the mid-1980s. The range-wide analysis showed quadratic, declining trends for the 1965-2007 and 1965-1985 timeframes. The quadratic trend was less certain for the 1986-2007 time period when male counts seemed to decline early in the time period and then slightly increase in the later period after 2000. In the Management Zone (MZ) analyses, declines in male counts were documented in 6 of 7 MZs for the time period of 1965-2007, 4 of 7 MZs for 1965-1985, and 2 of 7 for 1986-2007. In the 1986-2007 time period, 5 of 7 MZs had an unknown trend, a trend with no clear increase or decrease. In many cases this was due to an estimated short-term increase in the male count since about 2000. Analysis at the state level showed a similar pattern. Eight of 9 states exhibited declines from 1965-2007, while 4 of 9 illustrated declines from 1965-1985. Seven of the 11 states had unknown trends from 1986-2007 and 1 of 11 illustrated an increasing trend. In many of these cases there was a long-

term decrease followed by an apparent increase in the later period of the analysis. At the population level, of the 21 trends analyzed for the time period of 1965- 2007, 48% (n = 10/21) of populations demonstrated decreasing trends, 52% (n = 11/21) demonstrated unknown trends. For the time period of 1965-1985, 43% (n = 9/21) demonstrated decreasing male-count trends, 52% (n = 11/21) had unknown trends, and 5% (n = 1/21) illustrate an increasing trend. For the time period of 1986-2007, 10% (n = 3/29) demonstrated decreasing trends, and 90% (n = 26/29) had unknown trends. The current lek-based approach to data collection results in the potential for substantial bias in trend estimates regardless of analysis method. Future lek monitoring using a standardized approach across states based on a probability sampling design would increase both precision and accuracy of estimated trends.

INTRODUCTION

The decline of greater sage-grouse (*Centrocercus urophansianus*) populations has concerned naturalists and biologist for at least the last 90 years (Hornaday 1916, Braun 1995, Connelly and Braun 1997, Aldridge and Brigham 2003, Schroeder et al. 2004). The primary approach to monitoring greater sage-grouse populations during the last 30+ years has been to count males at traditional display sites (strutting grounds or leks) in the spring (Connelly et al. 2003). Although this approach has been questioned because of the biased nature of data collection and the unknown relationship of counts to population size (Jenni and Hartzler 1978, Beck and Braun 1980, Walsh 2002, Walsh et al. 2004), this remains the primary approach to monitor long-term trends of greater sage-grouse populations (Connelly et al. 2000, Connelly et al. 2003, Connelly et al. 2004). Standardized techniques for data collection were recommended by the Western Sage and Columbian Sharp-tailed Grouse Technical Committee (Technical

Committee) under the auspices of its parent organization the Western Association of Fish and Wildlife Agencies (WAFWA). WAFWA has signed two Memoranda of Understanding agreeing to collect trend data in a format recommended by the Technical Committee (Connelly et al. 2004, Stiver et al. 2006). Even so, standardized lek monitoring techniques still have not been uniformly implemented range-wide.

In 2005, the U.S. Fish and Wildlife Service (USFWS) responded with a 'not warranted' decision (U.S. Fish and Wildlife Service 2005) to multiple petitions to list the greater sage-grouse as either threatened or endangered in all of its range (Appendix A). A recent decision by B. Lynn Winmill (Chief U.S. District Judge, District of Idaho) remanded the original 2005 'not warranted' decision back to the USFWS for reconsideration. As a result, the USFWS issued a data call (U.S. Fish and Wildlife Service 2008) for the most recent information on greater sage-grouse populations and habitat to assist in their listing decision. Although each state is providing information on populations and habitat, WAFWA is leading the effort through the Technical Committee to provide data on trends in population indices. The objective of this report is to analyze trends in counts of male greater sage-grouse at leks over three time frames (1965-2007, 1965-1985, 1986-2007) and at four geographic scales (range-wide, management zone, population, and state) relevant to conservation and management.

METHODS

Lek Data

Because sage-grouse gather on traditional leks each spring, biologists typically use counts of displaying males as an index to track changes in breeding populations (Connelly et al. 2003). A large number of leks are monitored each year throughout North America; most states have >30 years of data and have conducted extensive searches for new leks. All state wildlife agencies

monitor sage-grouse breeding populations using data from leks, but methods for gathering these data vary somewhat among agencies and sometimes within agencies among years (Connelly et al. 2004). Each state provided lek count data for this report, including the counts of males and each lek's location.

All data for these analyses were collected prior to the decision to produce this report; therefore we are limited to the data available and the methods used to collect it. Because the data collection methods lacked a rigorous statistical approach, we attempted to standardize the lek data as much as possible to reduce potential biases. Complete standardization was not possible, because most states provided summary data rather than raw data, and individual states may have had slightly different criteria. For the purposes of thes analyses, we defined a lek as a specific geographic location at which ≥ 2 displaying males were counted in ≥ 2 years during the assessment period (1965-2007) (Connelly et al. 2003). We assumed that if a state reported count data for a specific lek, those data were spatially associated with the location reported for that lek. In practice, the definition of a lek is more complicated. For example, individual males can shift among lek locations within and between years, smaller "satellite" leks can form near leks with large numbers of males, and observers sometimes report multiple activity centers within a large group of displaying males as separate leks, all of which can affect count data reported for a specific lek location. To deal with these issues, we chose to group data from leks if they were $\leq$ 500 m of each other and counted in the same years, as males counted at those locations are likely to be the same 'group' of birds.

We based our analyses on the high (i.e., "maximum") count of displaying males reported in each year for each lek location. We assumed that count data provided by states were conducted using monitoring protocols that have been in use for >40 years (Jenni and Hartzler

1978, Beck and Braun 1980, Connelly et al. 2003). These protocols included visiting leks multiple times during the appropriate season (March-May) and at the appropriate time of day (typically between 0.5 hours before sunrise to 1.5 hours after sunrise) (Braun 1995, Schroeder et al. 2000, Beck et al. 2003). We eliminated data from leks for which the location was not reported because all leks needed to be assigned to specific populations and management zones. We also eliminated data from aerial counts, which are likely to have different detection probabilities than ground-based counts. Leks with different names but the same reported location were resolved prior to analysis.

We applied more specific criteria to count data from Wyoming. The Wyoming dataset became corrupted and had to be rebuilt from raw data to complete the analysis in a timely fashion. For Wyoming, we excluded: (1) visits before 15 March or after 15 May, (2) leks with < 2 visits per year; (3) counts conducted in the dark before sunrise (based on observer notes); (4) counts conducted after 0800 hours (approximately 1.5 hours after sunrise early in the year); (5) counts in which disturbance (e.g., eagle attack, vehicle traffic) clearly reduced the count; (6) counts in which males and females were not differentiated; and (7) duplicate records (i.e., those with the same observer, date, time, and count). Because lek attendance typically declines later in the morning, excluding counts after 0800 hrs is unlikely to influence the maximum male count.

Other features of the dataset should also be noted. We excluded data from many leks in South Dakota because they lacked location information. We also excluded data from Colorado prior to 1986 because numerous errors in the state's database prior to 1986 could not be resolved in time for inclusion in these analyses. In North Dakota, all lek counts were conducted during the third week of April, but the state has used this approach >30 years.

Statistical Assumptions

The lek count data contained many missing values (years in which no count was conducted at a given lek). Given limited information available as to why a lek was not counted in a particular year and the short time-frame for this analysis, we assumed the data were missing completely at random (Rubin 1976, Gelman et al. 2003). This assumption requires that the probability of all possible patterns of missing data are the same for all values of the missing data and the probability of all possible patterns of observed data are the same for all values of the missing data (Rubin 1976). No missing values were imputed. Thisassumption about missing data is likely not valid in all cases, but we lacked information to model the missing data process.

One problem associated with missing values should be noted with this data set. Because the current sampling scheme is lek-based rather than area-based, locations are not considered a lek and therefore, not reported in databases, until grouse are found using them. Therefore, very few leks in the data set started with a zero. As a result, the initial establishment of a lek with a small number of male grouse and its concurrent increase from zero to a positive number of grouse is missing from these data, while long sets of zero counts often exist after a lek has become inactive. This could lead to negatively biased estimates of trend in male count.

Measurement error is known to exist in the count data. Measurement error arises from several sources including variation in detectability, observer acuity, and number of counts conducted for a given lek in a year. The number of counts within a given year is important because increasing the number of counts within a year increases the chance of getting a higher male count. Therefore, if the number of counts of a lek within a year has increased over time, then the trend could be positively biased. We did not have data on the number of counts per lek for all states, therefore we could not fully evaluate the magnitude of this potential problem. We

were unable to adjust for detectability or observer acuity in this analysis. Low and variable detection probabilities are known to be problematic for count data (Anderson 2001, Walsh 2002), but we had no data with which to address the issue. Effects of detectability and observer acuity are unknown and likely vary through time.

Analysis Methods

To address whether indices of abundance increased or decreased over time, the data only allowed us to estimate the trend in male counts. Although estimating trend in population size would be preferable, the lack of suitable techniques for estimating population size for sage-grouse makes this approach impractical. The trend in male counts (i.e., base count on *y*-axis in graphs) was estimated using a set of linear mixed-effects models (Jiang 2007). We use the term 'base count' to refer to the base level of the model upon which all of the random effects vary. Other analysis options exist such as route regression, Bayesian hierarchical models, and splines, but we chose the linear mixed-model approach because it is robust, treats each lek as having its own trend, and could be completed within the time frame allotted for the analysis. The response variable for the analyses was natural log transformed high male count plus one. We added one to counts because the natural log of zero is undefined. The predictor variable was year. All analyses used a hierarchical nesting of counts within leks. The range-wide analysis also nested leks within states because sampling effort varied across states. We fit three models for each data set: (1) a constant count model, (2) a linear trend in count model, and (3) a quadratic trend in count model. The structure of the constant model was:

$$\log\left(Y_{ij}+1\right)=\beta_{0i}$$

$$\beta_{0i}\sim N(\beta_0,\sigma_0^2)$$

Y_{ij} = high count at lek i in year j

i = lek identification

j = year identification.

The structure for the linear model was:

$$\log\left(Y_{ij}+1\right)=\beta_{0i}+\beta_{1i}X_{ij}$$

$$\beta_{0i}\sim N(\beta_0,\sigma_0^2)$$

$$\beta_{1i}\sim N(\beta_1,\sigma_1^2)$$

$$\text{Cov}\left(\beta_0,\beta_1\right)=\psi$$

Y_{ij} = high count at lek i in year j

X_{ij} = year of sampling for lek i in year j

i = lek identification

j = year identification.

The structure for the quadratic model was:

$$\log\left(Y_{ij}+1\right)=\beta_{0i}+\beta_{1i}X_{ij}+\beta_{2i}X_{ij}^2$$

$$\beta_{0i}\sim N(\beta_0,\sigma_0^2)$$

$$\beta_{1i}\sim N(\beta_1,\sigma_1^2)$$

$$\beta_{2i}\sim N(\beta_2,\sigma_2^2)$$

$$\text{COV}=\begin{bmatrix}\sigma_0^2 & \rho_{01} & \rho_{02}\\ \rho_{01} & \sigma_1^2 & \rho_{12}\\ \rho_{02} & \rho_{12} & \sigma_2^2\end{bmatrix}$$

Y_{ij} = high count at lek i in year j

X_{ij} = year of sampling for lek i in year j

i = lek identification

j = year identification.

In these models, the fixed effects are mean log male count plus one, intercept, and slopes. The random effects are lek-specific differences from the fixed effects. Model selection was performed using the Akaike Information Criterion (AIC) (Akaike 1973, Burnham and Anderson

2002) unless a model failed to converge on a maximum likelihood solution, in which case it was eliminated from consideration. All models were fit in program R version 2.6.1 (R Development Core Team 2007) using the *lme* function in the *nlme* package. The analysis was conducted at four geographic scales: (1) range-wide, (2) management zone (Appendix B), (3) population (Appendix C and D), and (4) state. The analysis was also performed for three time periods: (1) 1965-2007, (2) 1965-1985, and (3) 1986-2007. The starting year of 1965 was the starting point requested by the U. S. Fish and Wildlife Service. The break approximates time periods before (1965-1985) and after (1986-2007) widespread sagebrush eradication programs (Connelly et al. 2004). For each time period, the starting year was defined as year 1. In some cases, data were not available for the entire time span in which case all available data were included, in which case inferences are limited to the time span of the data.

Because no standard procedure exists to present confidence bands that incorporate uncertainty in both random and fixed effects when the number of counts per lek varies, we present graphical results for the fixed effects trends with 95% confidence bands showing only sampling variation based on formulae in Feldman (1988). Confidence bands do not include among-lek variation, so they represent a minimum level of uncertainty in trend estimates. Moreover, if the confidence limits at the beginning of a period overlap those at the end of a period, there is little evidence for a change in lek count. Plots of trends are presented as 'base counts' which represent the base level from which each lek is offset.

To provide a quantitative illustration as to the increasing or decreasing nature of the trends and a comparison to results in Connelly et al. (2004), we calculated average annual rates of change for each trend line. We used the geometric mean of the annual proportional changes in

the trend line (n = 42 intervals for 1965-2007; n = 20 for 1965-1985; n = 21 for 1986-2007) to properly weight those trend lines with steep increases or decreases.

In this analysis, leks contributed to the overall trend based on the number of times they were sampled. Because leks were not sampled from a probability-based design, no weighting scheme could be applied. Instead, leks were given equal weight regardless of size if they were sampled in the same number of years. Because population change is a multiplicative process (population size this year times growth rate equals population size next year), growth rate rather than starting lek size will dominate inference over a long time series. Attempting to weight leks by size (i.e., no. of males counted) would have been inappropriate because the size of each lek changes over time.

RESULTS

Range-wide Lek-count Trends

Data from 3,419 individual leks and 34,441 maximum counts contributed to the range-wide trend analysis for 1965-2007 (Table 1). All new lek locations reported between 2003 and 2007 fell within or immediately adjacent to previously-defined population and management zone boundaries (Connelly et al. 2004, Stiver et al. 2006) and were assigned to a population and management zone accordingly. Although other information was available, these data represent the most consistent statewide counts conducted using accepted protocols. The number of leks counted that met criteria for inclusion in the trend analysis increased 928% over the assessment period, from 221 in 1965-1969 to 2,271 in 2005-2007 (Fig. 1). Average maximum males per lek and median maximum males per lek declined from the 1965-1969 through 1995-1999 analysis periods and increased slightly from 1995-1999 to 2005-2007 (Fig. 2). Overall, mean maximum

number of males per lek was similar from 24.2 per lek to 23.9 males per lek from 1965-2007 (Fig. 2). The long-term trend analysis showed a measurable trend of -3.1% for the 1965-2007 period (Table 1, Fig. 3). Although the decreasing trend appeared to be larger during 1965-1985 than 1986-2007, no detectable trend, defined as the beginning of the period having a confidence interval higher than then end of the trend, was identified for the later period (Table 1). Range-wide leks showed substantial variation in trends in male counts ($SD(\beta_1) = 0.19$, $SD(\beta_2) = 0.004$), but less variation in male counts across states ($SD(\beta_1) = 0.010$, $SD(\beta_2) < 0.0001$).
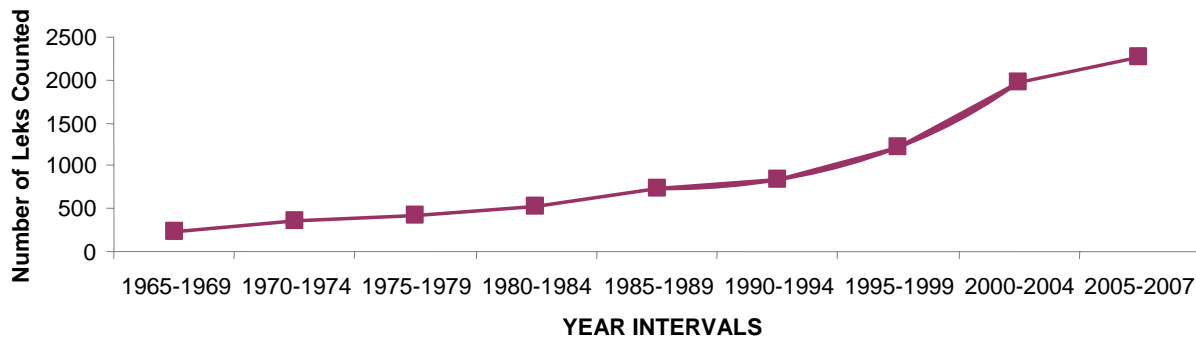
Figure 1. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, throughout the range.
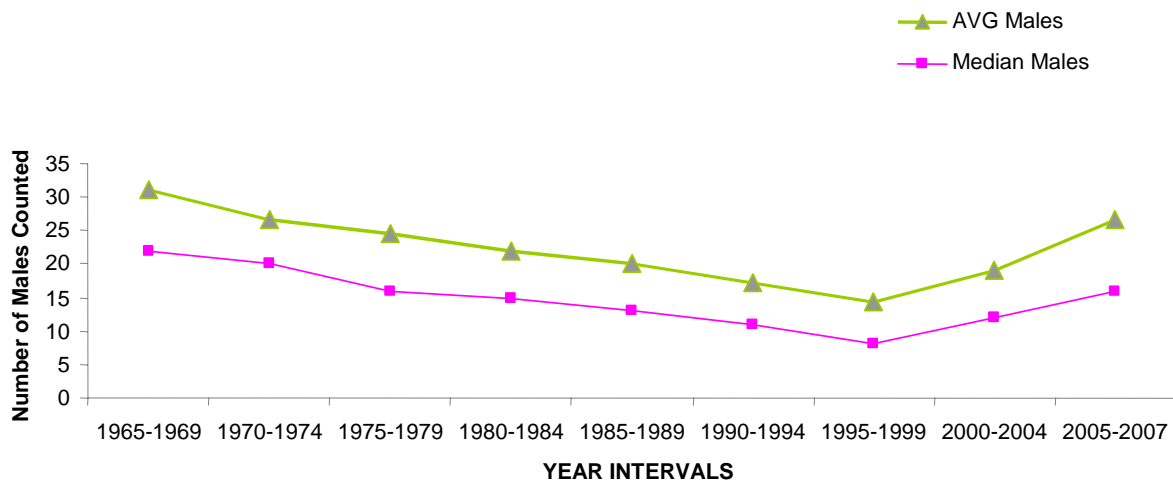
Figure 2. Range-wide mean and median maximum count of males per lek during 5-year time intervals from 1965-2007.

$$y = 3.520 - 0.087x + 0.0013x^2$$
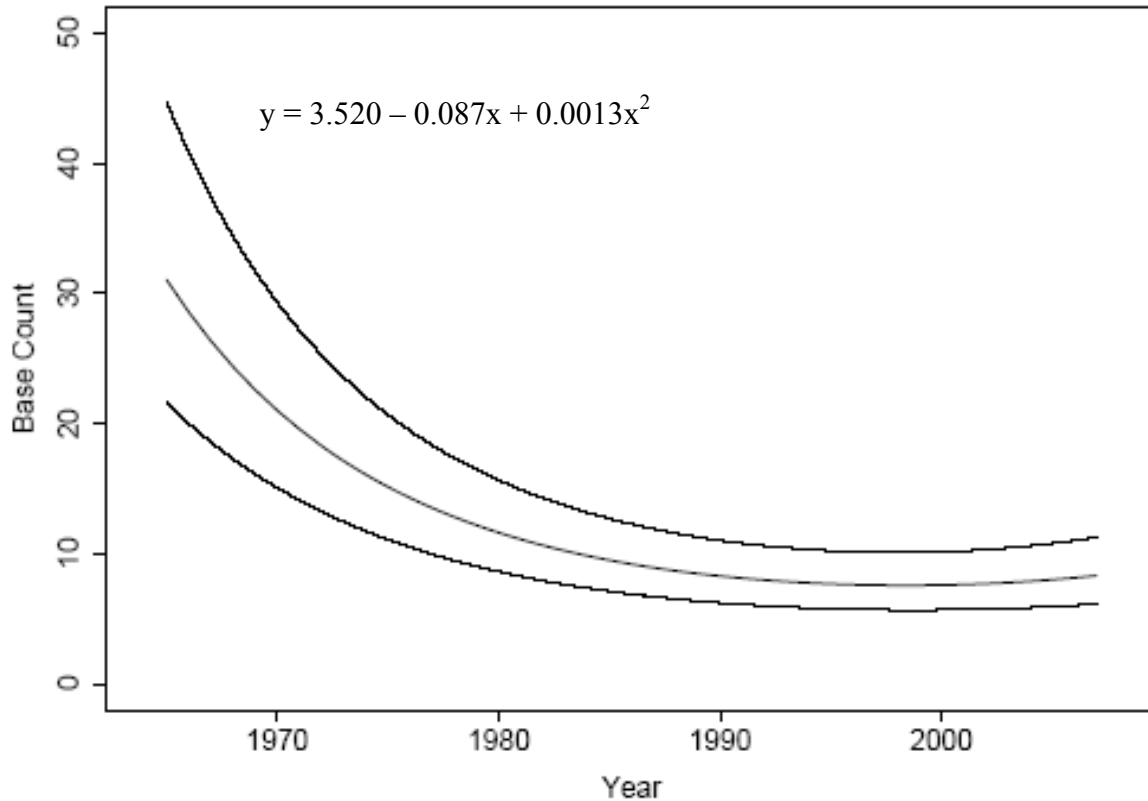
Figure 3. Range-wide trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007. Trends incorporate data from both active and inactive leks.

Lek-count Trends by Management Zone

Management Zone I-Great Plains. Data from 692 individual leks contributed to the trend analysis for Management Zone I (MZ-I, Table 1). The number of leks counted that met criteria for inclusion in the trend analysis increased 1,169% over the assessment period, from 32 in 1965-1969 to 406 in 2005-2007 (Fig. 4). Average maximum males per lek and median maximum males per lek varied over time and increased from the earliest (1965-1969) to the latest (2005-2007) analysis periods (Fig. 5). Overall, lek size increased from 18.5 males per lek to 22.7 males per lek (Fig. 5). The long-term trend analysis showed a decreasing measurable

trend during 1965-2007 (Fig. 6), but no detectable trends were identified for the 1965-1985 or 1986-2007 analysis periods (Table 1). Leks in MZ-I showed substantial variation in trends in male counts (SD(β_1) = 0.212, SD(β_2) = 0.004).
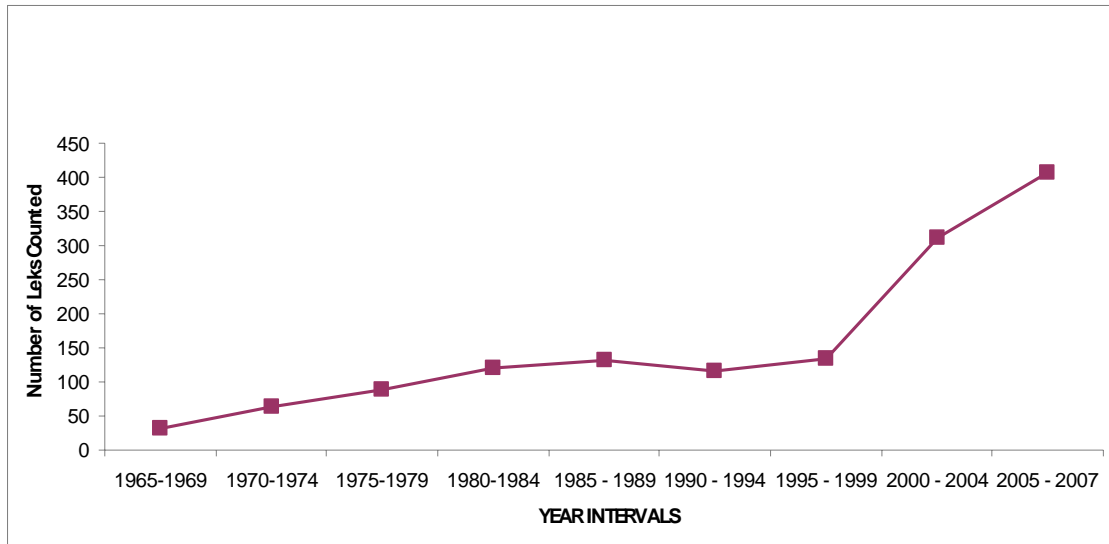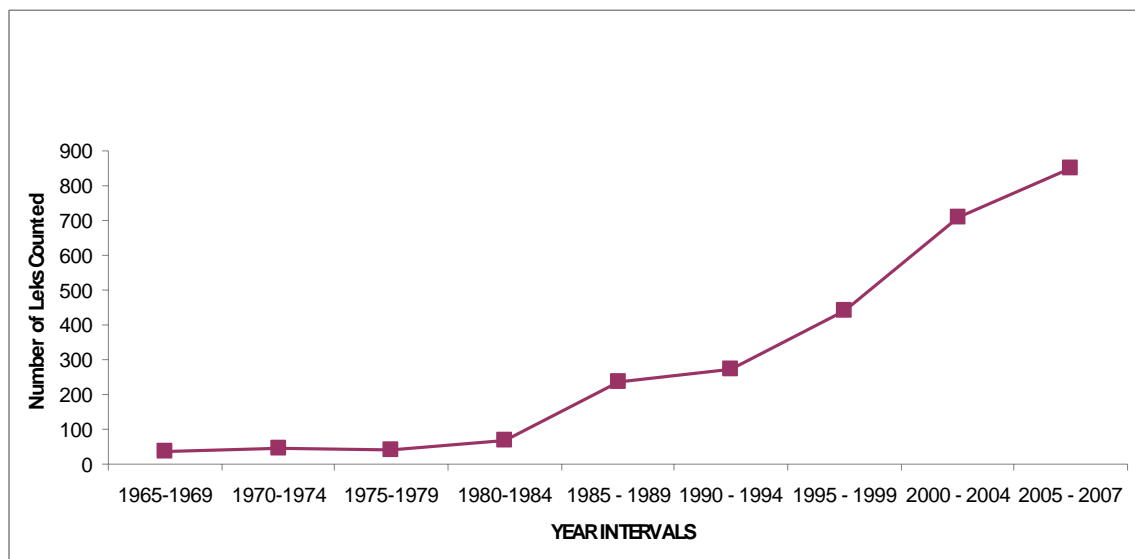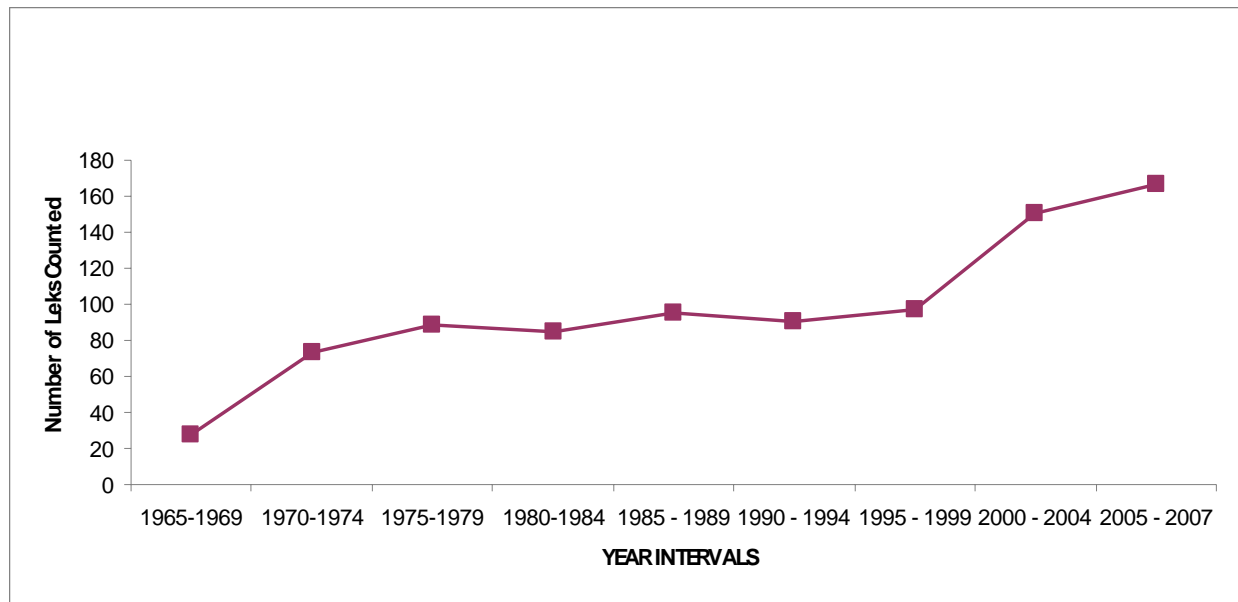

Figure 4. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in MZ-I.
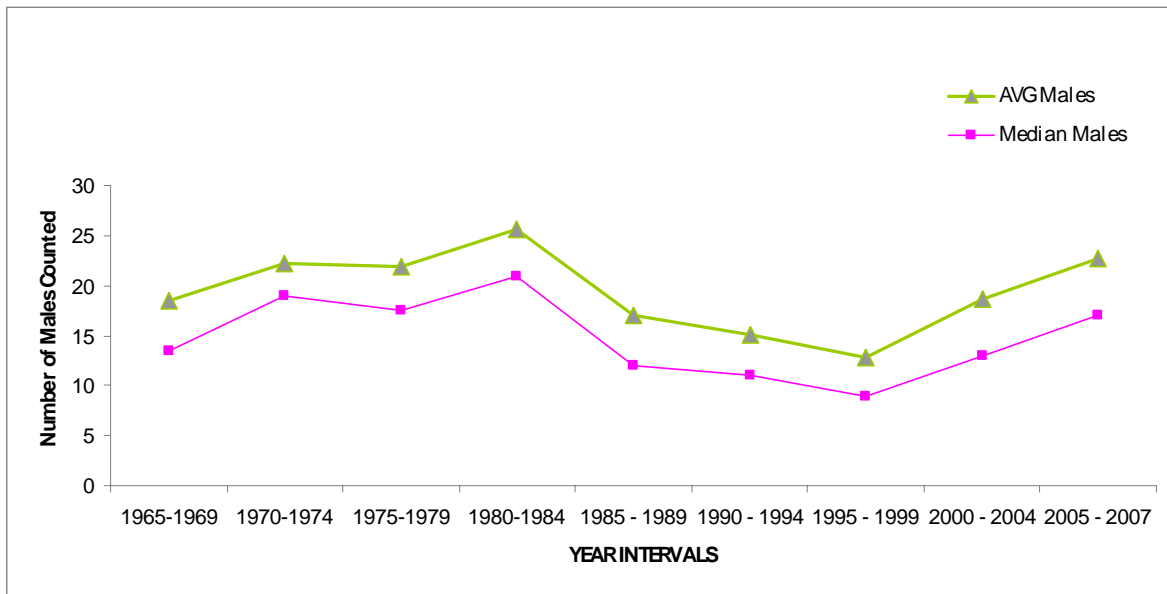
Figure 5. The mean and median maximum number of males counted on leks during time intervals from 1965 - 2007 in MZ-I.
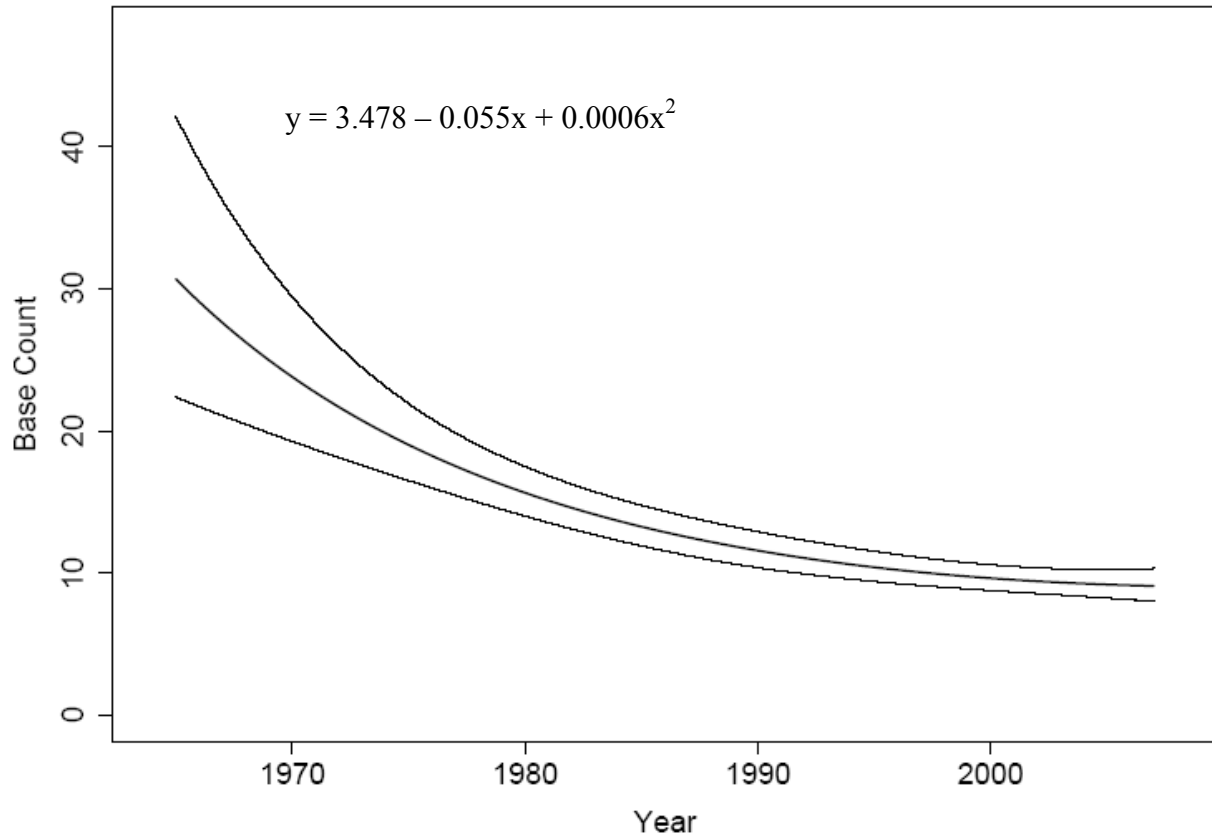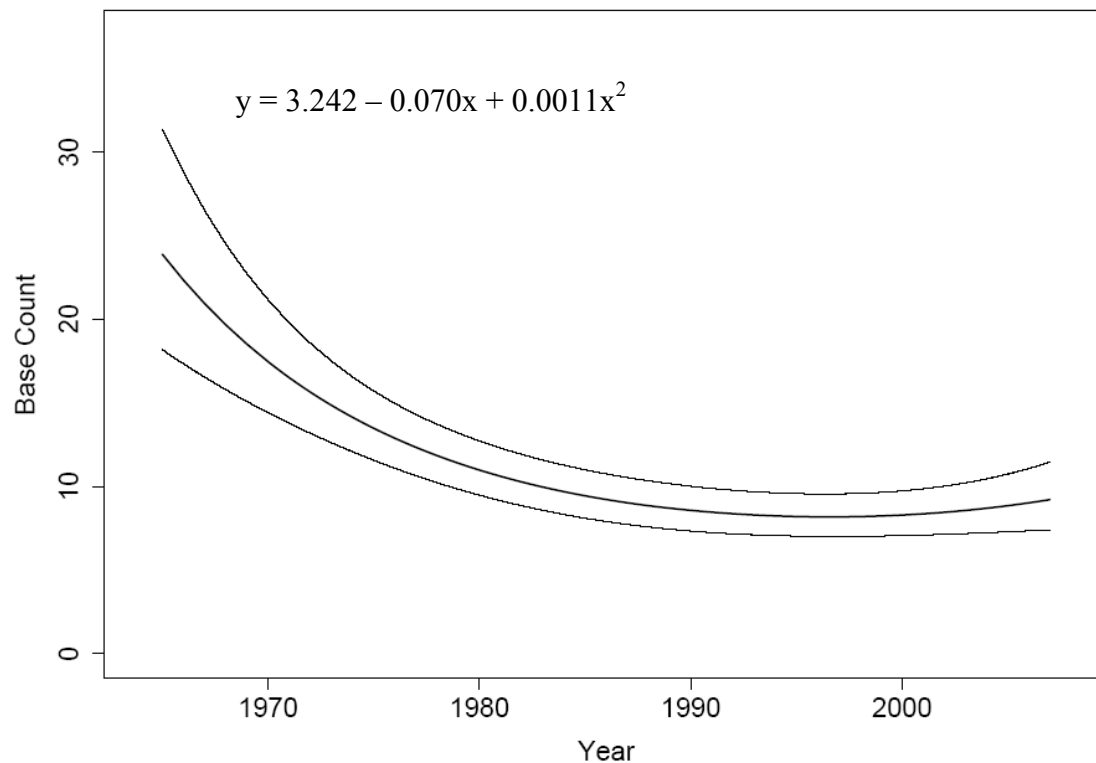
Figure 6. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965 - 2007 in MZ-I. Trends incorporate data from both active and inactive leks.

Management Zone II-Wyoming Basin. Data from 1,242 individual leks contributed to the trend analysis for Management Zone II (MZ-II, Table 1). The number of leks increased over the assessment period by 2,132%, from 38 in 1965-1969 to 848 in 2005-2007 (Fig. 7). Average maximum males per lek and median males per lek declined from 1965-1969 to 1975-1979, increased slightly in 1980-1984 and declined again to a low in 1995-1999. Both the mean and median maximum males per lek increased sharply in 2000-2004 and again in 2005-2007, approaching values seen in the 1970's but still below the values reported for the 1965-1969

period. Lek size decreased from 44.5 in 1965-1969 to a low of 17.1 males per lek in 1990-1994

and increased to 35.5 in 2005-2007. The median males per lek declined from 33.0 in 1965-1969

to 17.0 in 1975-1979, increased slightly to 19.0 males per lek in 1980-1984, and then declined

sharply to 9.0 males per lek in 1995-1999 and increased to 23.0 males per lek in 2005-2007 (Fig.

8). Although the long-term trend analysis (1965-2007) indicated a measurable decline (Fig. 9),

the 1965-1985 period showed a measurable decline while the 1986-2007 period illustrated a

detectable increase (Table 1). Leks in MZ-II showed substantial variation in trends in male
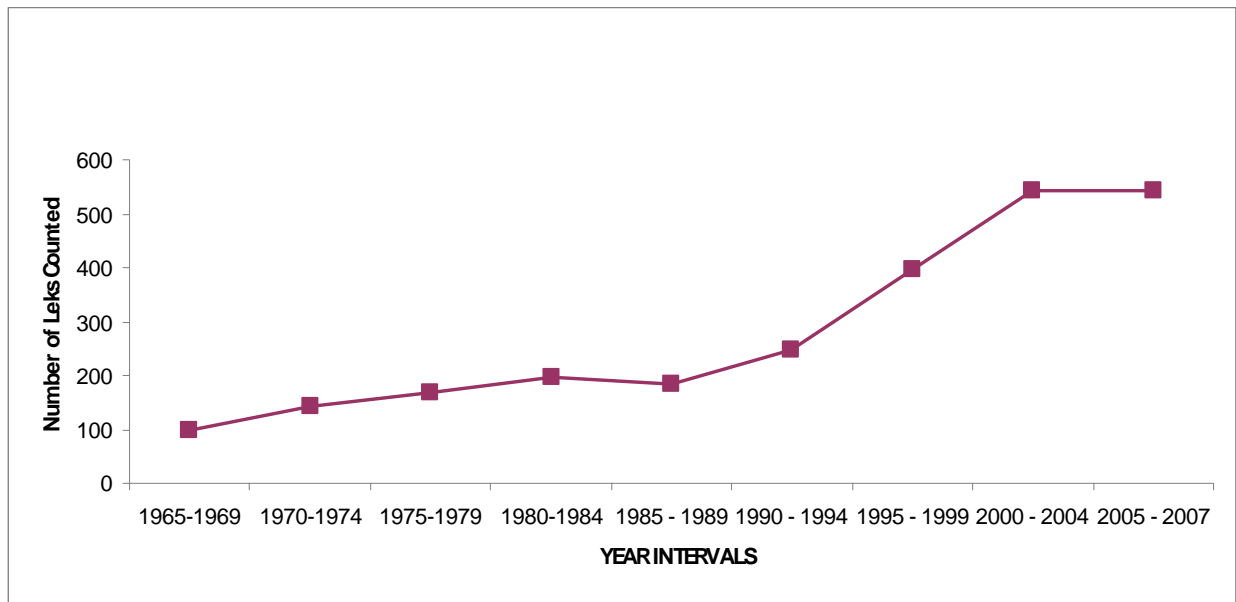
counts $(SD(\beta_1) = 0.188, SD(\beta_2) = 0.003)$.

Figure 7. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-
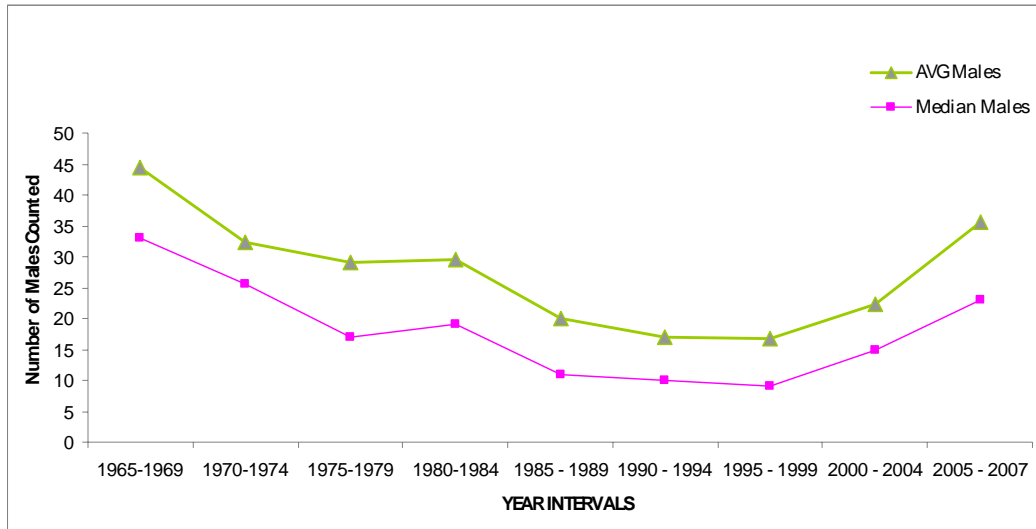
2007, in MZ-II.

Figure 8. Mean and median maximum number of males counted per lek during time

intervals from 1965 to 2007 in MZ-II.

$$y = 4.723 - 0.1364x + 0.002x^2$$
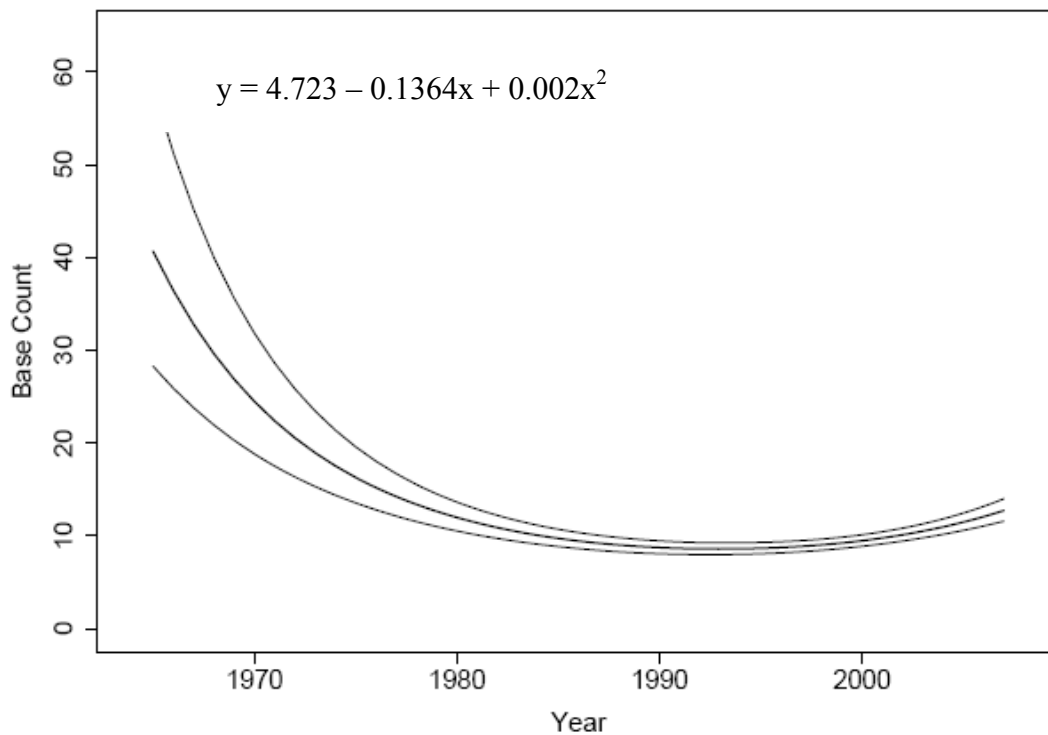
Figure 9. The trend and the 95% confidence intervals represent a fixed effect change in male

count at the base level of the linear model, 1965-2007 in MZ-II. Trends incorporate data from

both active and inactive leks.

Management Zone III-Southern Great Basin. Data from 218 individual leks contributed to the trend analysis for Management Zone III (MZ-III, Table 1). The number of leks counted that met criteria for inclusion in the trend analysis increased 493% over the assessment period, from 28 in 1965-1969 to 166 in 2005-2007 (Fig. 10). Average maximum males per lek and median males per lek varied over time and increased slightly between the 2000-2004 and 2005-2007 analysis periods (Fig. 11). Overall, lek size was similar over the long-term and averaged 24 males per lek for both the 1965-69 and 2005-2007 analysis periods (Fig. 11). The trend analysis indicated a measurable declining trend for the long-term (Fig. 12) and 1965-1985 analysis period; no detectable trend was identified for the 1986-2007 period (Table 1). Leks in MZ-III showed substantial variation in trends in male counts ($SD(\beta_1) = 0.13$, $SD(\beta_2) = 0.003$)

Figure 10. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in MZ-III.
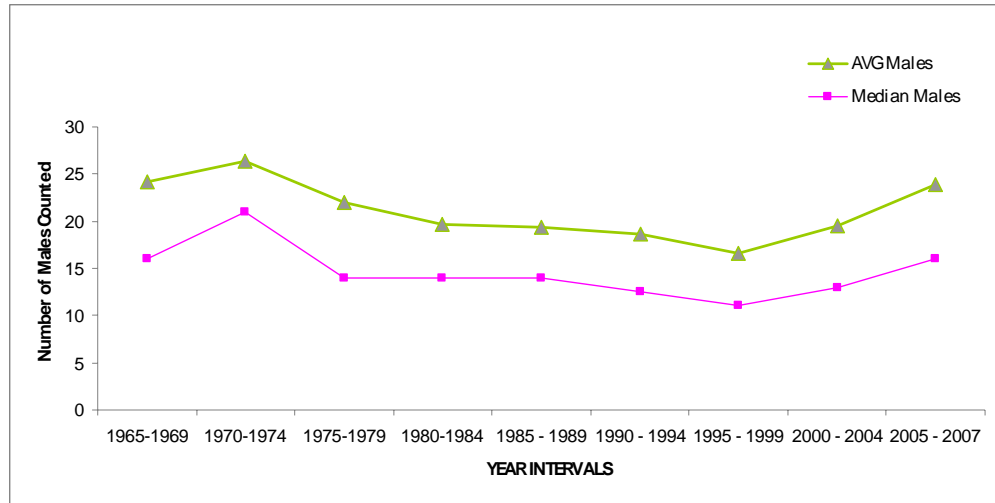
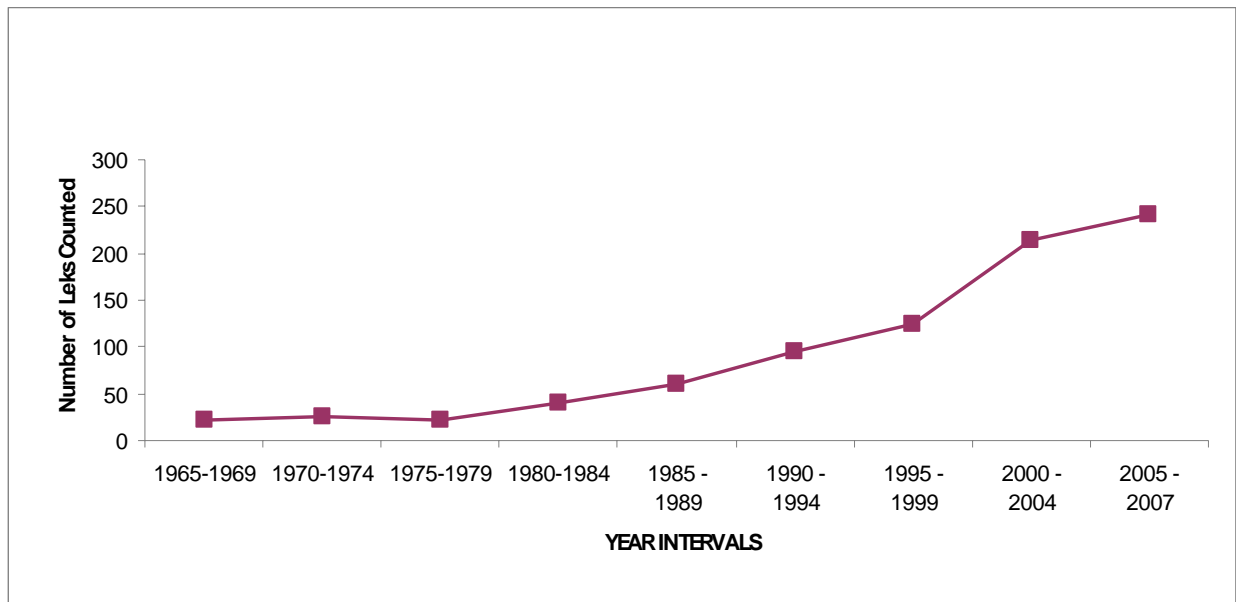Figure 11. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in MZ-III.

$$y = 3.242 - 0.070x + 0.0011x^2$$

Figure 12. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in MZ-III. Trends incorporate data from both active and inactive leks.

Management Zone IV- Snake River Plain. Data from 852 individual leks contributed to the trend analysis for Management Zone IV (MZ-IV, Table 1). The number of leks counted that met criteria for inclusion in the trend analysis increased 444% over the assessment period, from 100 in 1965-1969 to 544 in 2005-2007 (Fig. 13). Average maximum males per lek and median males per lek varied over time but generally decreased from the early (1965-1989) to late (2005-2007) analysis periods (Fig. 14). Overall, lek size decreased from 34.2 to 19.9 males per lek but there was some increase from 1995-1999 (11.3 males per lek) to 2005-07 (19.9 males per lek) (Fig. 14). The trend analysis indicated measurable decreasing trends for all intervals (Table 1, Fig. 15). Leks in MZ-IV showed substantial variation in trends in male counts (SD(β_1) = 0.186, SD(β_2) = 0.004).

Figure 13. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in MZ-IV.
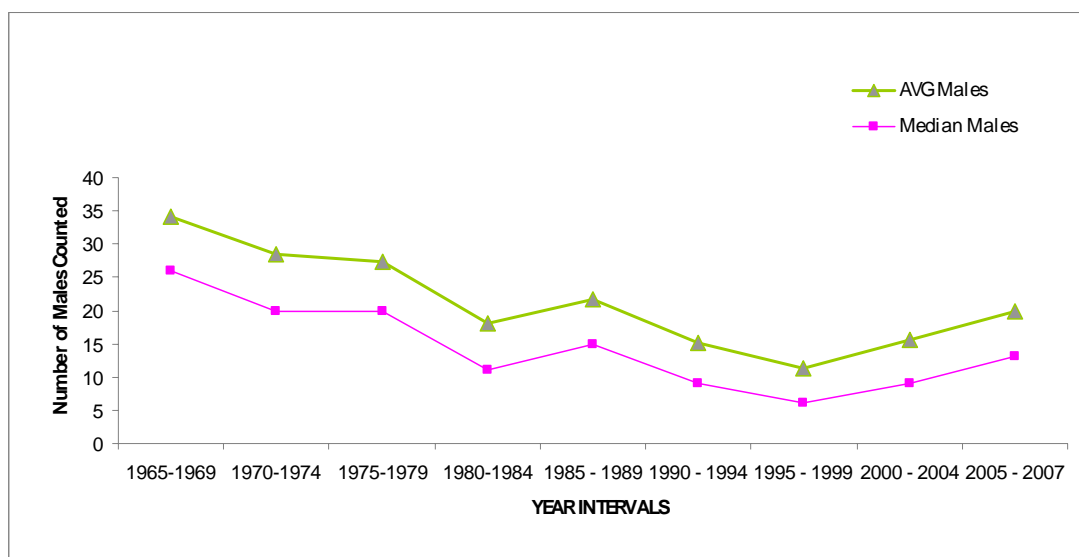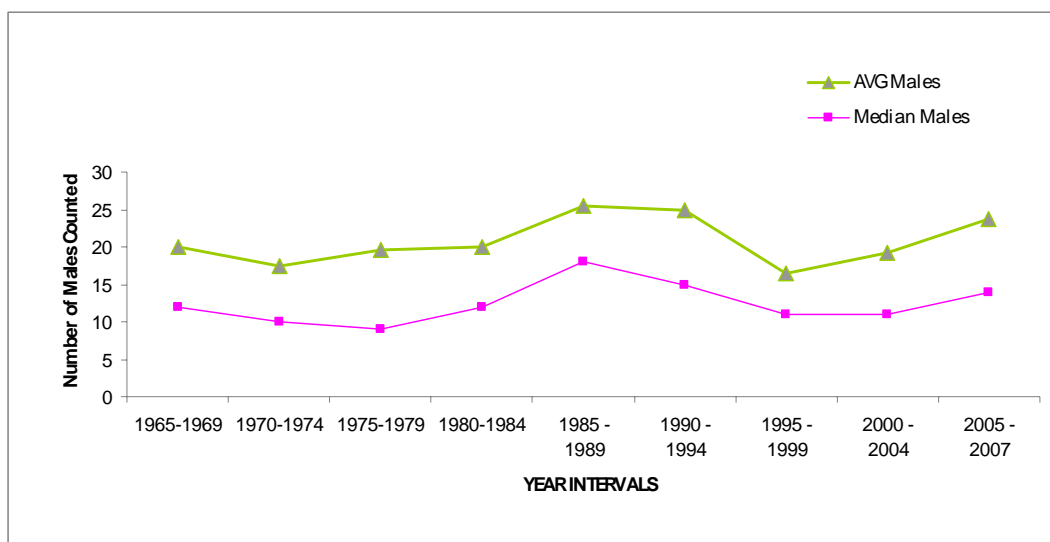
Figure 14. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in MZ-IV.
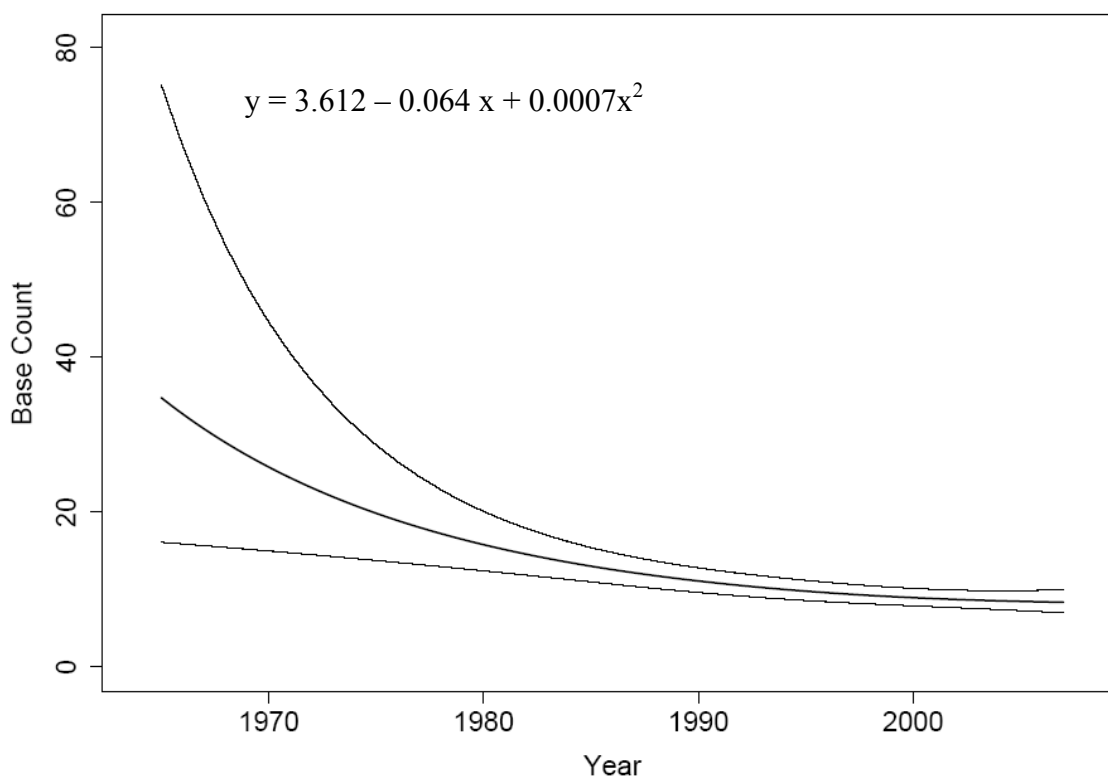

$$y = 3.630 - 0.098x + 0.001x^2$$
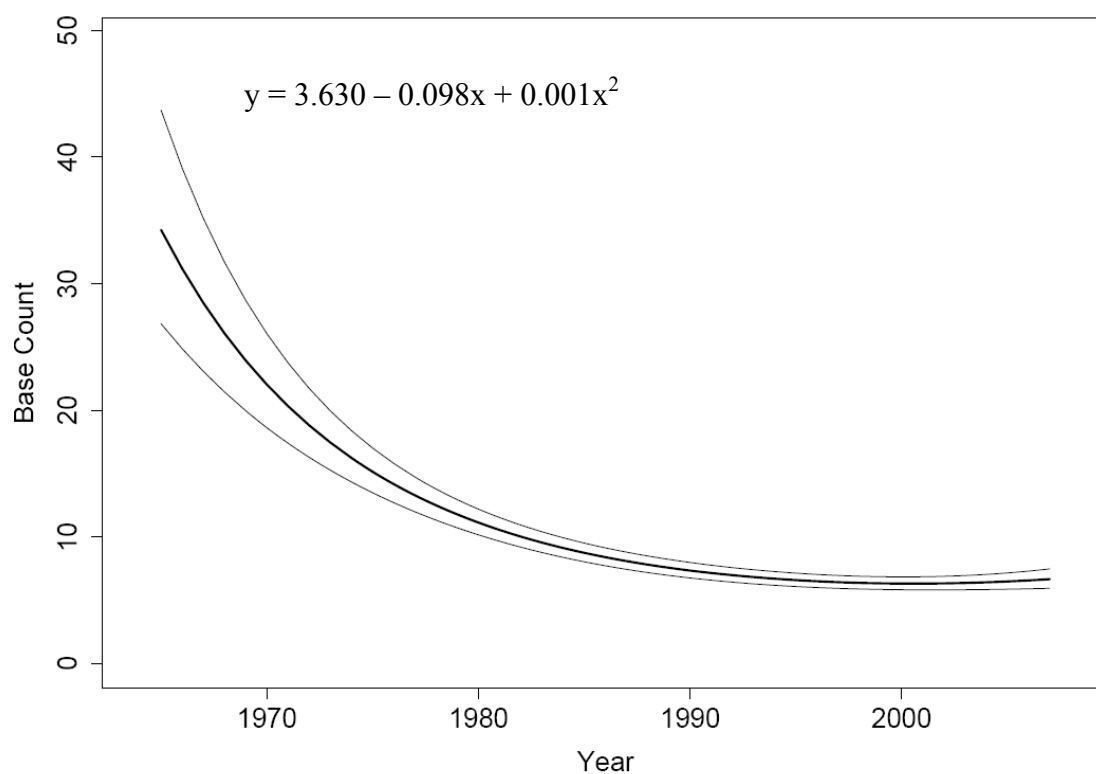
Figure 15. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in MZ-IV. Trends incorporate data from both active and inactive leks.

Management Zone V-Northern Great Basin. Data from 341 individual leks contributed to the trend analysis for Management Zone V (MZ-V, Table 1). The number of leks counted that met criteria for inclusion in the trend analysis increased 1,000% over the assessment period, from 22 in 1965-1969 to 242 in 2005-2007 (Fig. 16). Average maximum males per lek and median males per lek varied over time and increased slightly from the early (1965-1989) to the late (2005-2007) analysis periods (Fig. 17). Overall, lek size increased from 20.1 per lek to 23.7 males per lek but there was a slight decline from 1990-94 to 2005-07 (Fig. 17). Trend analysis illustrated a measurable decreasing trend for the long-term (Fig. 18) and 1986-2007 analysis period; no detectable trend was identified for the 1965-1985 period (Table 1). Leks in MZ-V showed substantial variation in trends in male counts ($SD(\beta_1) = 0.288$, $SD(\beta_2) = 0.005$).
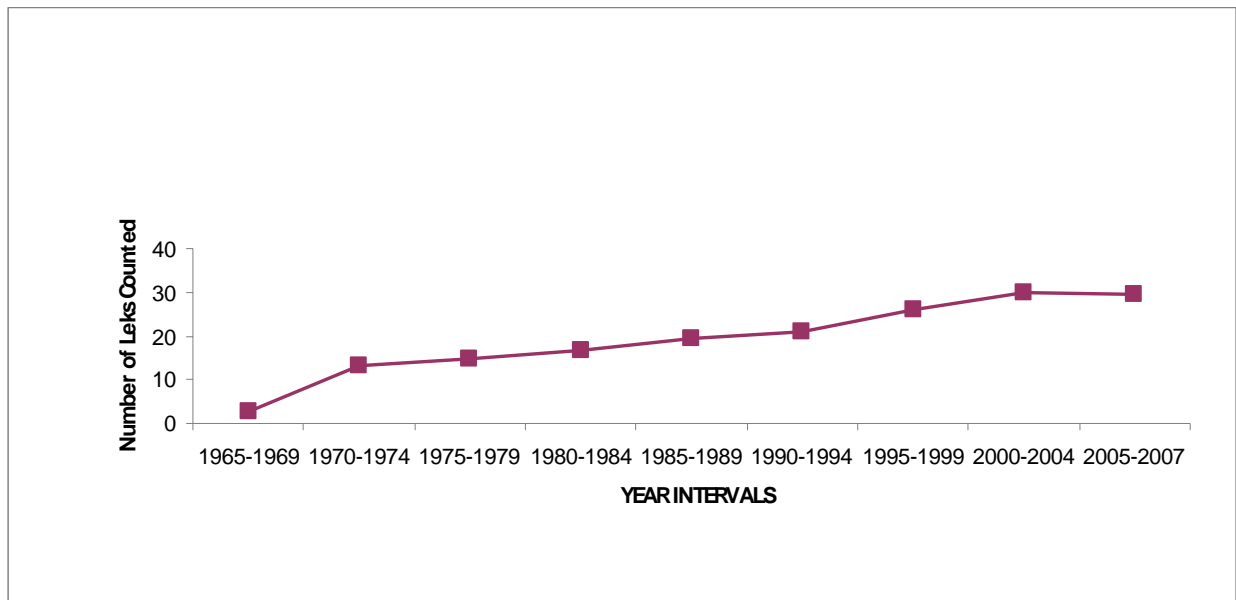

Figure 16. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in MZ-V.
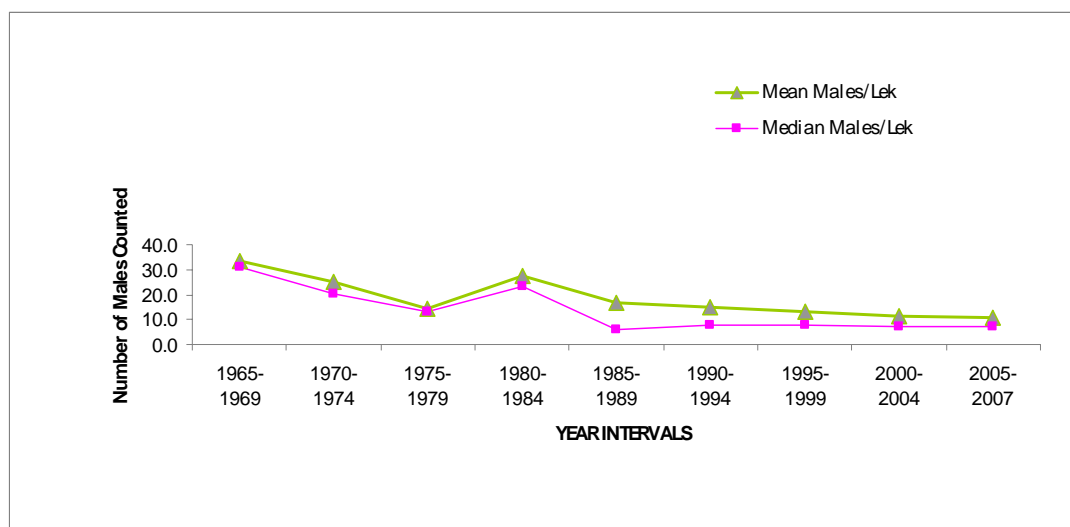
Figure 17. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in MZ-V.
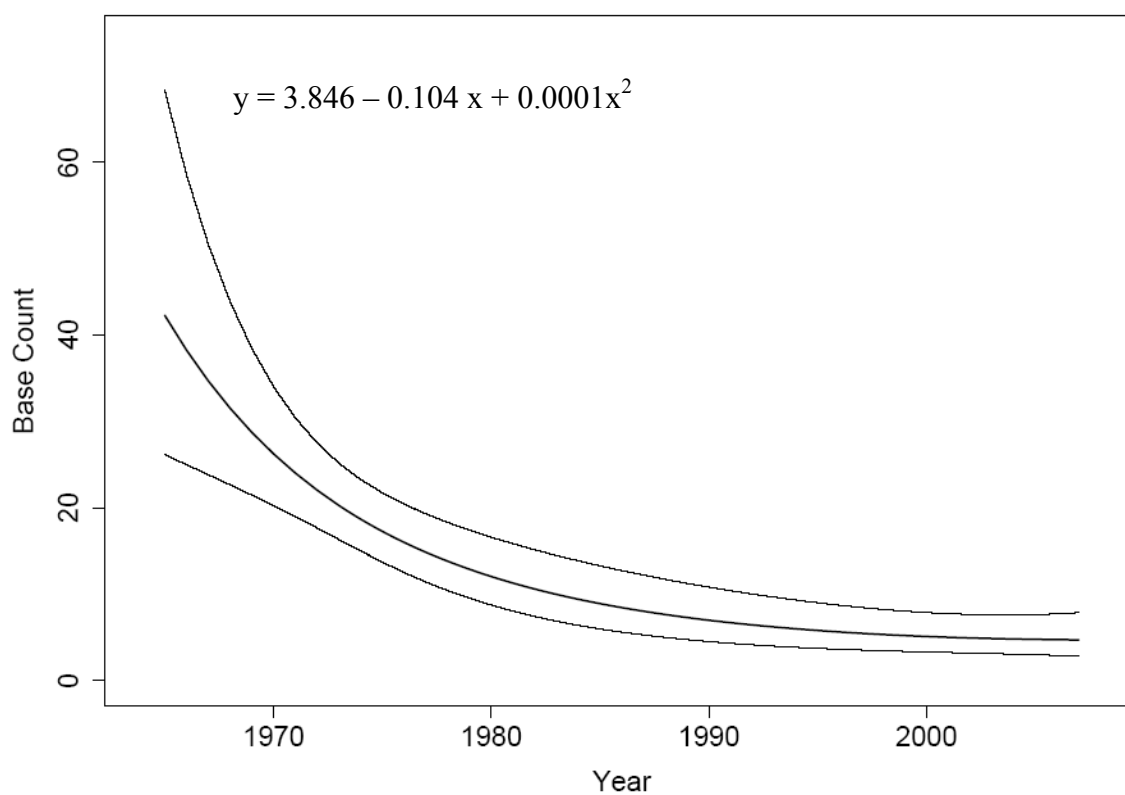

$$y = 3.612 - 0.064\,x + 0.0007x^2$$

Figure 18. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965 - 2007 in MZ-V. Trends incorporate data from both active and inactive leks.

Management Zone VI-Columbia Basin (Washington). Management Zone VI (MZ-VI) consists of leks only found within Washington. Data from 36 individual leks contributed to the trend analysis for MZ-VI (Table 1). The number of leks counted that met criteria for inclusion in the trend analysis increased 1,054% over the assessment period, from 2.6 in 1965-1969 to 30 in 2005-2007 (Fig. 19). Average maximum males per lek and median males per lek decreased from the early (1965-1985) to the late (1986-2007) analysis periods (Fig. 20). Overall, mean number of males per lek decreased from 33.2 to 10.8 males per lek (Fig. 20). Trend analysis illustrated a measurable decreasing trend for the long-term (Fig. 21) and 1965-1985 analysis period; no detectable trend was identified for the 1986-2007 period (Table 1). Leks in MZ-VI showed substantial variation in trends in male counts (SD(β_1) = 0.178, SD(β_2) = 0.004).
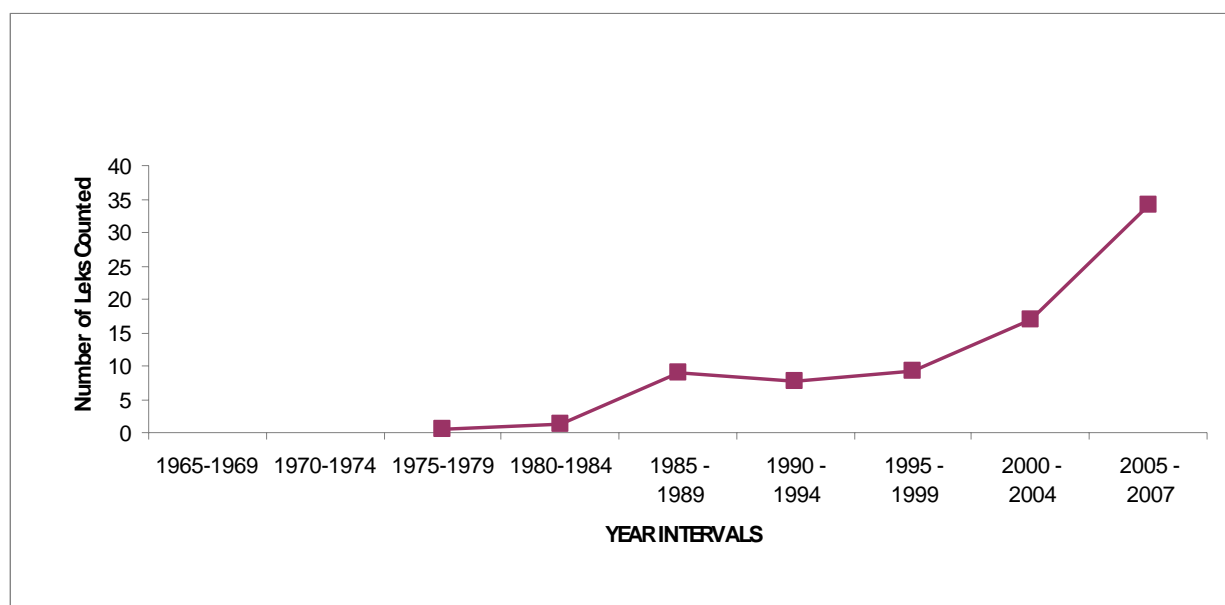

Figure 19. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in MZ-VI (Washington).

Figure 20. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in MZ-VI (Washington).
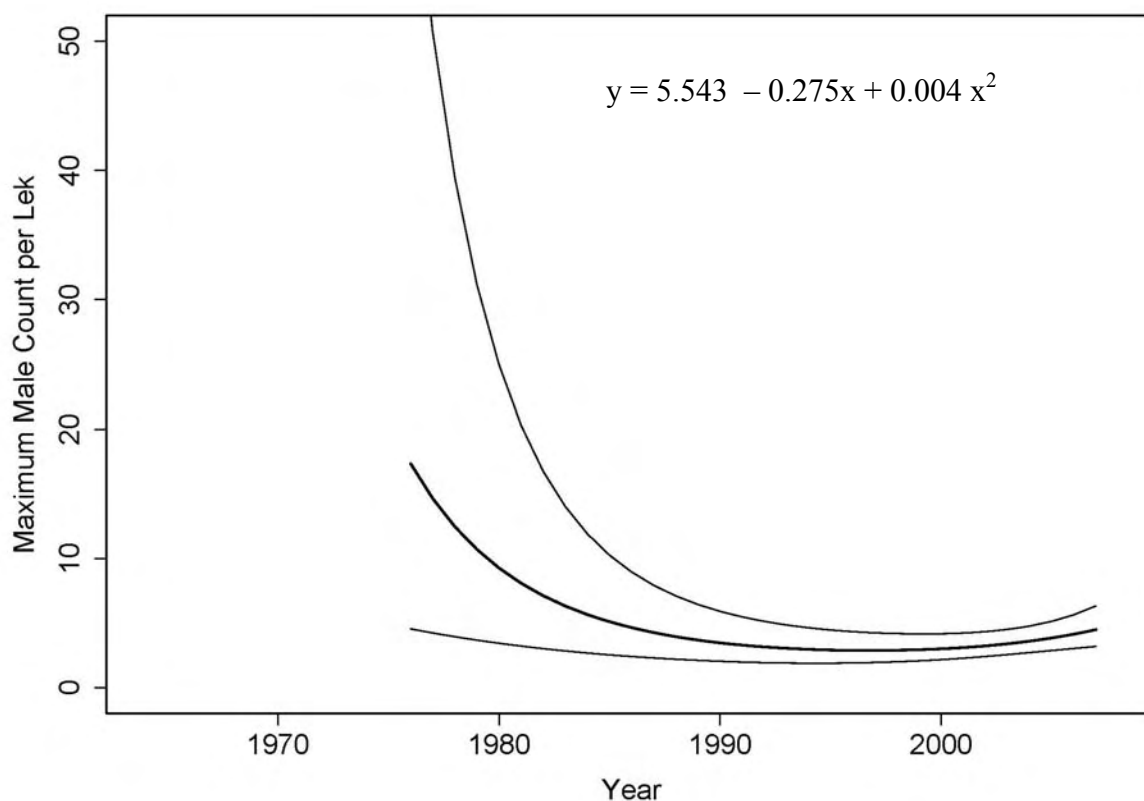

$$y = 3.846 - 0.104\,x + 0.0001x^2$$

Figure 21. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in MZ-VI (Washington). Trends incorporate data from both active and inactive leks.

Management Zone VII –Colorado Plateau. Data from 38 individual leks contributed to
trend analysis for Management Zone VII (MZ-VII, Table 1). The number of leks counted that
met criteria for inclusion in the trend analysis increased over the assessment period over from 1
in 1975-1979 to 34 in 2005-2007 (Fig. 22). Average maximum males per lek declined from
1975-1979 to 1980-1984, increased slightly in 1985-1987 and declined again. The average
seemed to stay steady from 1990-1994 through 2005-2007. The median males/lek declined from
16.0 in 1975-1979 to zero in 1990-1994 and increased to 5.0 males per lek in 2005-2007 (Fig.
23). No detectable trend was identified for any analysis period (Table 1, Fig. 24).

Figure 22. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1975-
2007, in MZ-VII.
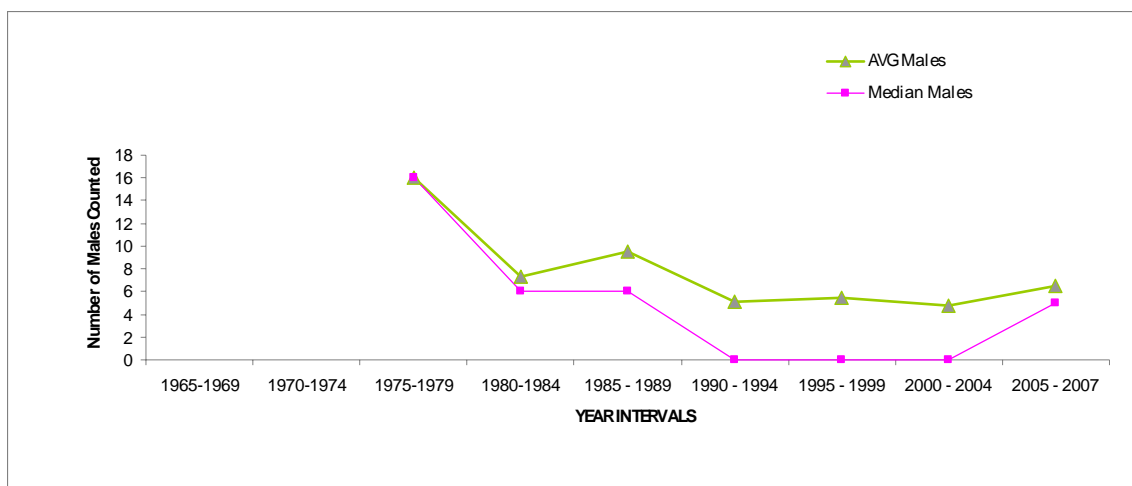
Figure 23. Mean and median maximum number of males counted per lek during time intervals from 1965 to 2007 in MZ-VII.
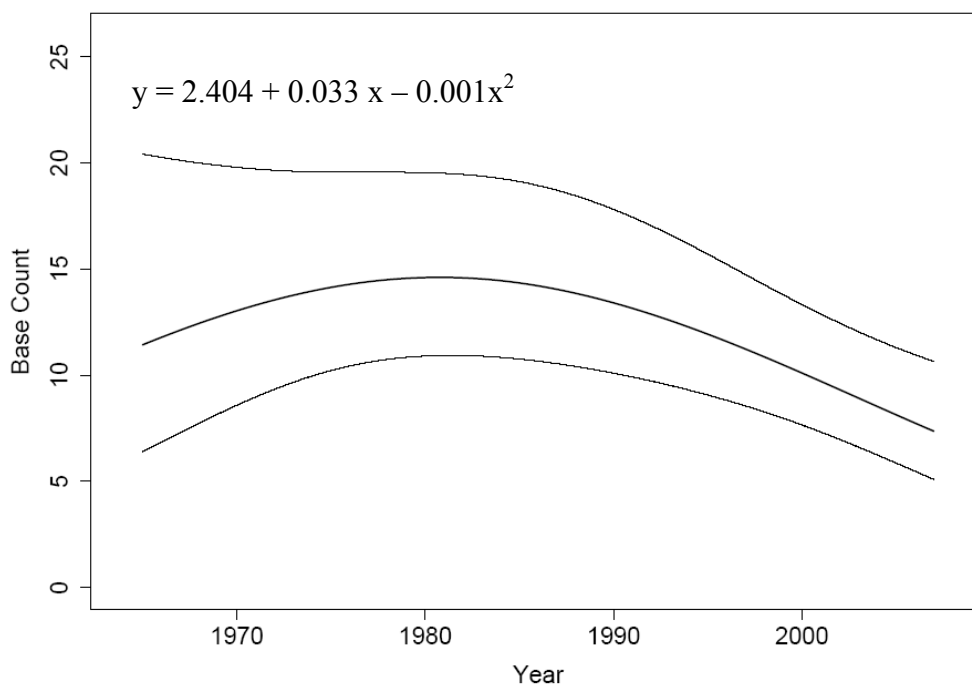

$$y = 5.543 - 0.275x + 0.004\ x^2$$

Figure 24. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model, 1965-2007 in MZ-VII. Trends incorporate data from both active and inactive leks.

Lek-count Trends by State

     California. Data from 76 individual leks contributed to the 1965-2007 trend analysis for California (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased 336% over the assessment period, from 11 in 1965-1969 to 48 in 2005-2007 (Fig. 25). Average maximum males per lek and median maximum males per lek varied over time and increased slightly from the early (1965-1989) to the late (2005-2007) analysis periods (Fig. 26). Overall, lek size increased from 19.5 to 20.4 males per lek but there was some decline from 1990-94 to 2005-07 (Fig. 26). The long-term trend analysis illustrated a general decline (Table 2, Fig. 27). Nevertheless, a measurable negative trend was only detected for the 1986-2007 analysis period (Table 2). Leks in California showed substantial variation in trends in male counts ($SD(\beta_1) = 0.13$, $SD(\beta_2) = 0.003$)
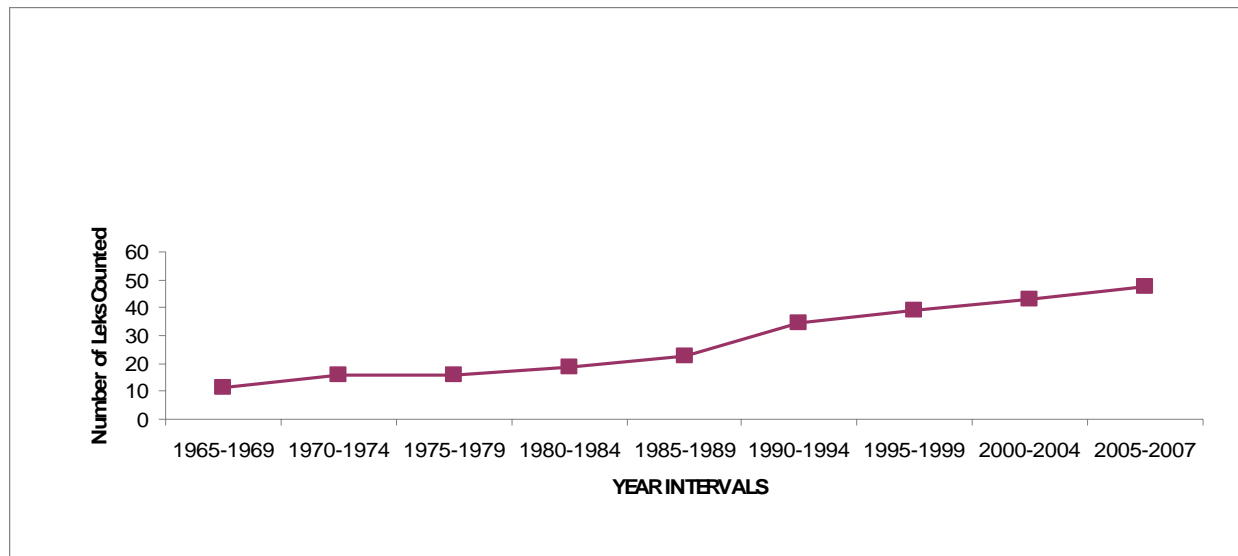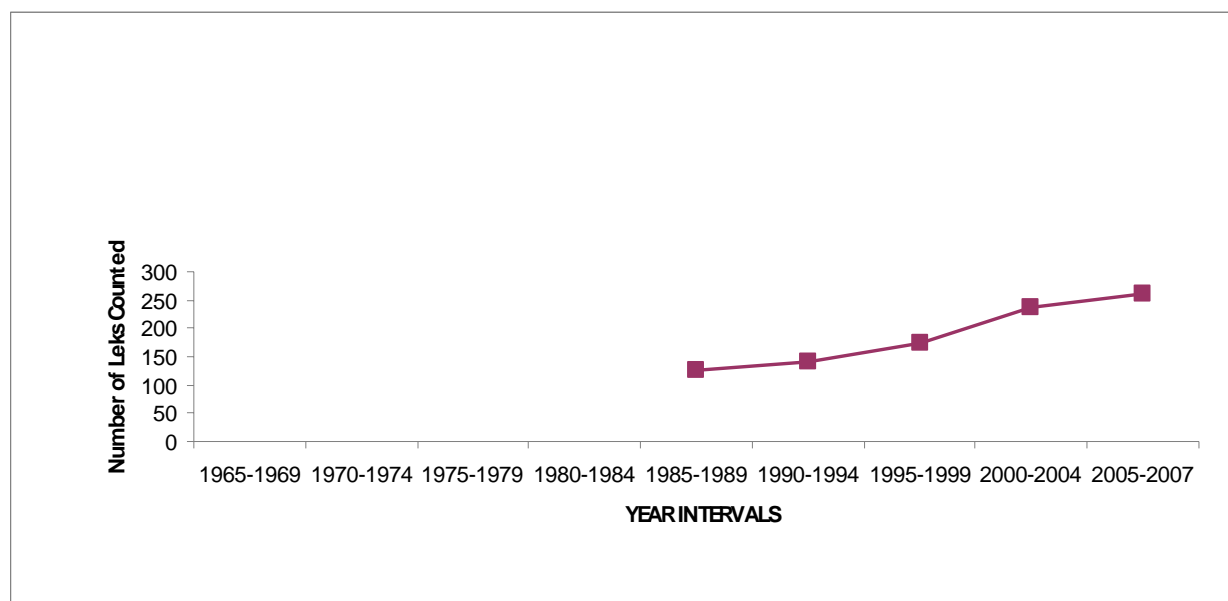

Figure 25. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in California.
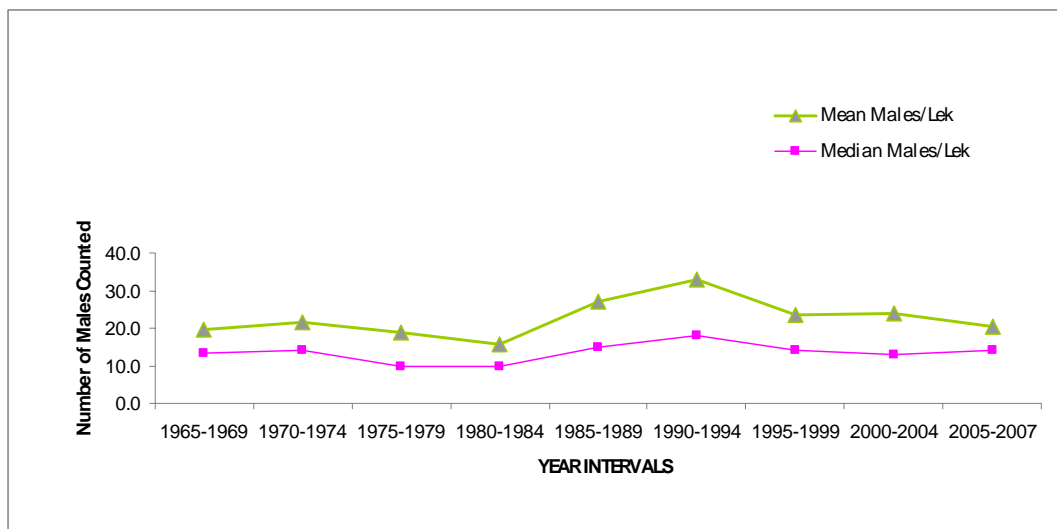
Figure 26. Mean and median maximum number of males counted per lek during 5-year time intervals from 1965-2007 in California.
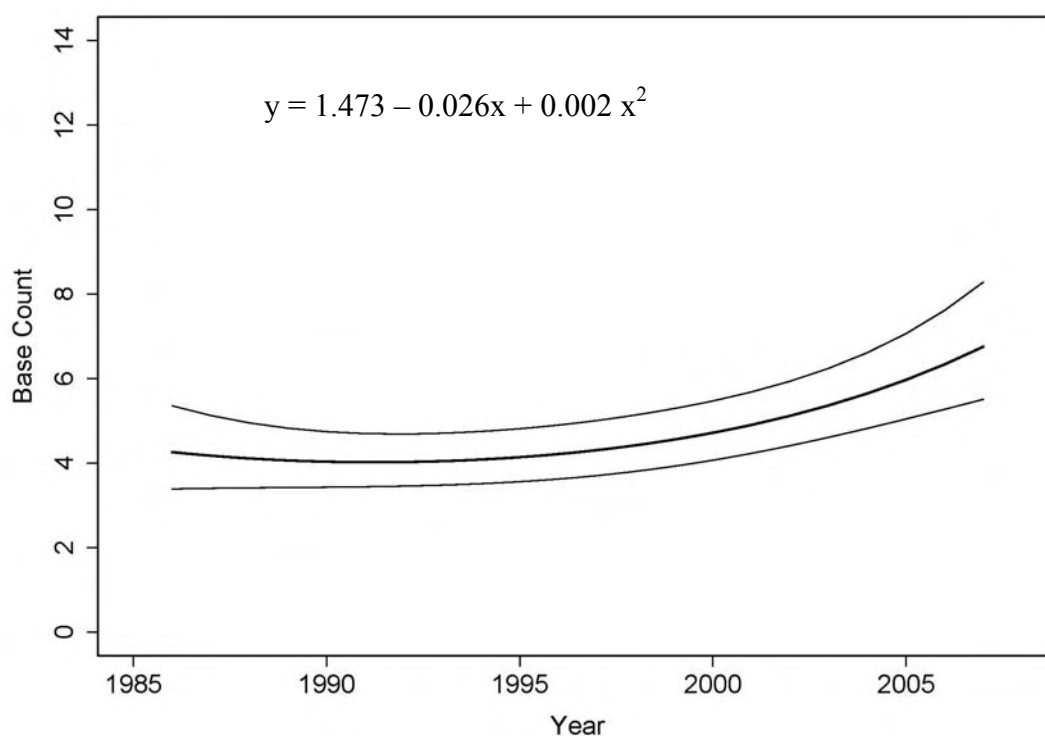

$$y = 2.404 + 0.033 \, x - 0.001x^2$$

Figure 27. Trend and 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in California. Trends incorporate data from both active and inactive leks.

Colorado. Lek-count data prior to 1986 in Colorado were not used in this analysis because discrepancies in the database could not be resolved in the time frame allotted for analysis. Counts were conducted prior to 1986 although they were in limited locations of the state that may not be representative for the entire state. Nevertheless, data from 295 individual leks contributed to the trend analysis for Colorado (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased 108% over the assessment period, from 125 in 1986-1989 to 260 in 2005-2007 (Fig. 28). Average maximum males per lek and median maximum males per lek varied over time and increased slightly from 14.5 per lek to 18.4 males per lek from the 1986-1989 to the 2005-2007 analysis periods (Fig. 29). The long-term trend analysis illustrated a measurable increasing trend during 1986-2007 (Table 2, Fig. 30). Leks in Colorado showed substantial variation in trends in male counts (SD(β_1) = 0.28, SD(β_2) = 0.01).

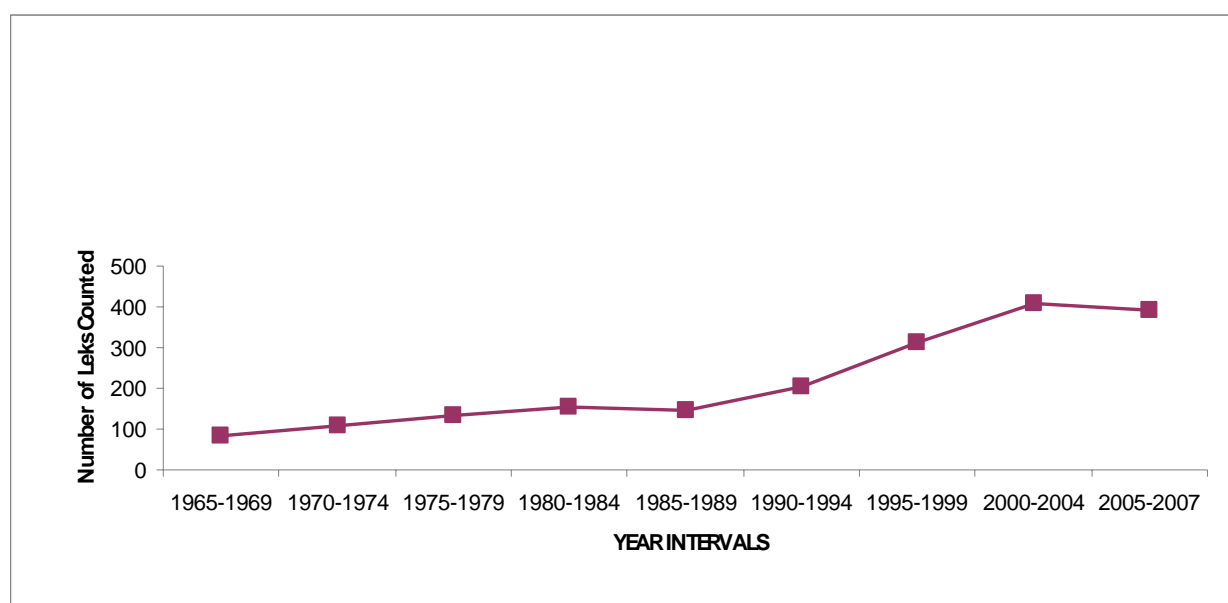Figure 28. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1986-2007, in Colorado.
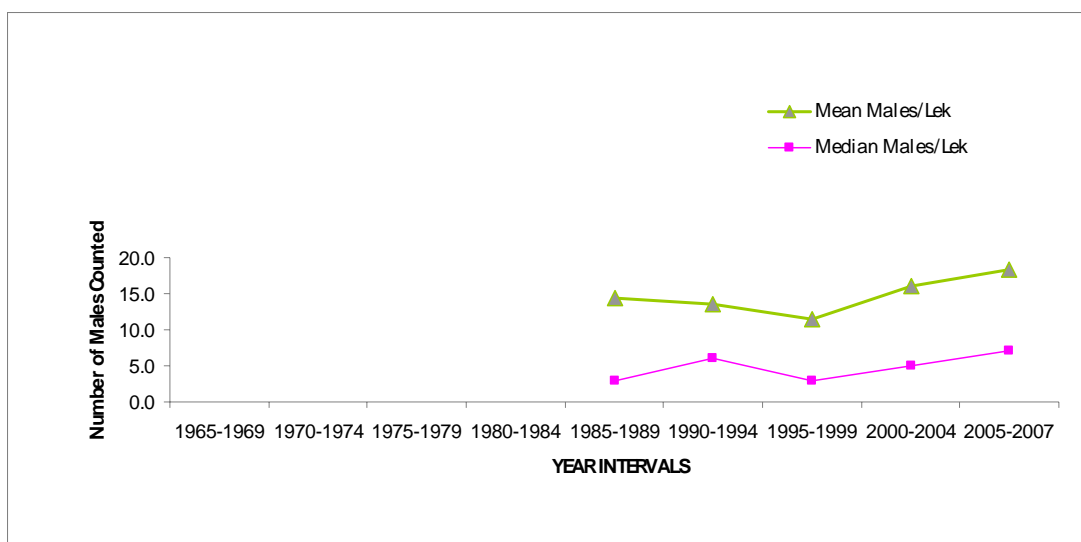
Figure 29. Mean and median number maximum of males counted per lek during time intervals from 1986-2007 in Colorado.
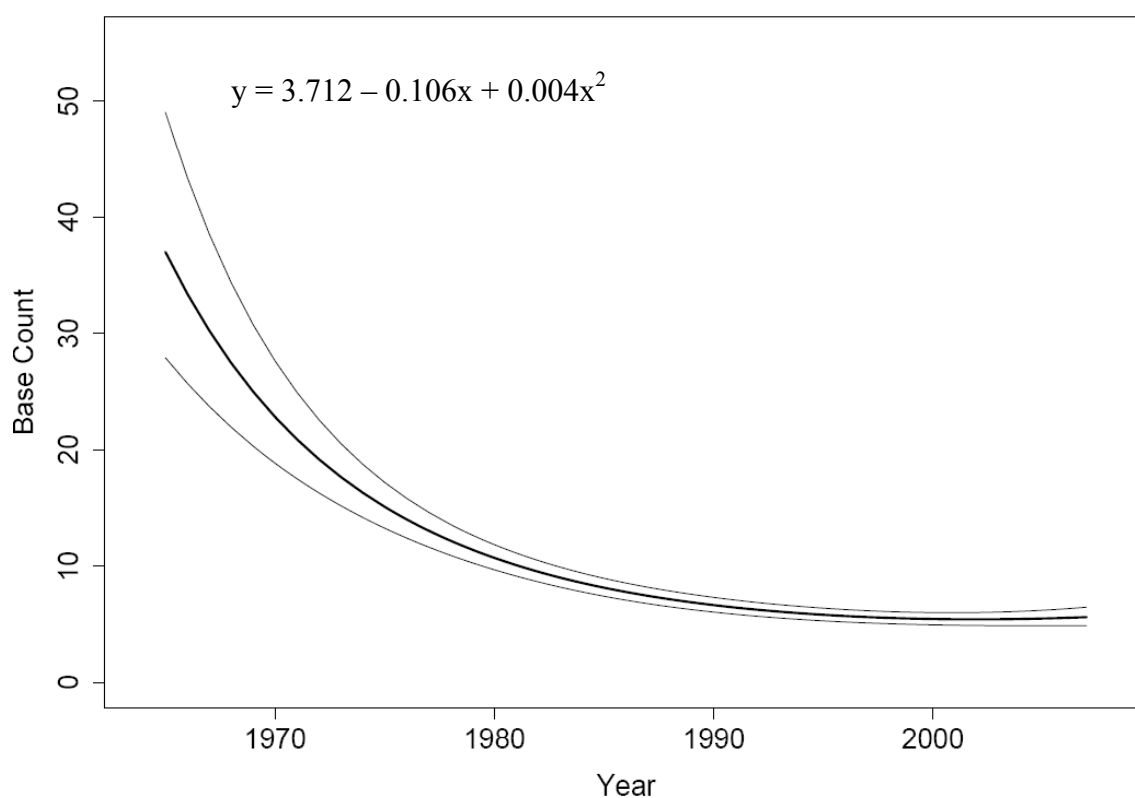

$$y = 1.473 - 0.026x + 0.002\ x^2$$

Figure 30. Trend and 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1986-2007 in Colorado. Trends incorporate data from both active and inactive leks.

Idaho. Data from 628 individual leks contributed to the trend analysis for Idaho (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased 383% over the assessment period, from an average of 81 during 1965-1969 to an average of 391 during 2005-2007 (Fig. 31). Average maximum males per lek and median maximum males per lek varied over time but decreased from 1965-1969 to 1995-1999 and then increased somewhat from 1995-1999 to 2005-2007 (Fig. 32). Overall, lek size decreased from 35.5 to 19.4 males per lek from 1965-07 and median males per lek showed the same pattern (Fig. 32). Trend analysis indicated measurable declines for all analysis periods (Table 2, Fig. 33). Leks in Idaho showed substantial variation in trends in male counts ($SD(\beta_1) = 0.19$, $SD(\beta_2) = 0.004$).
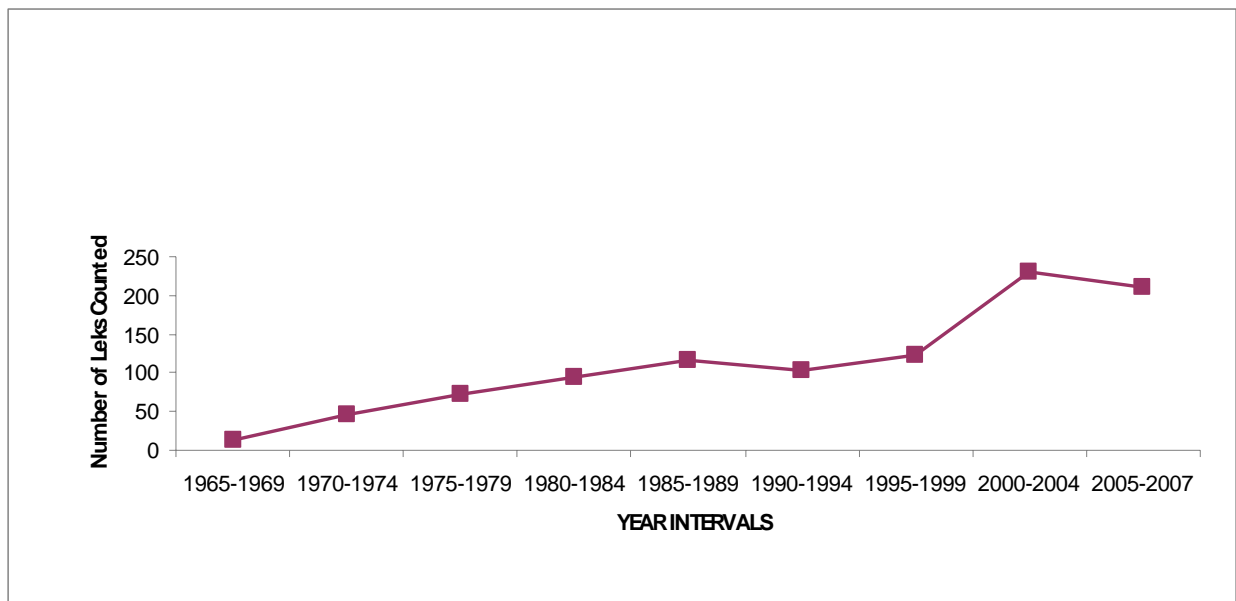

Figure 31. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in Idaho.
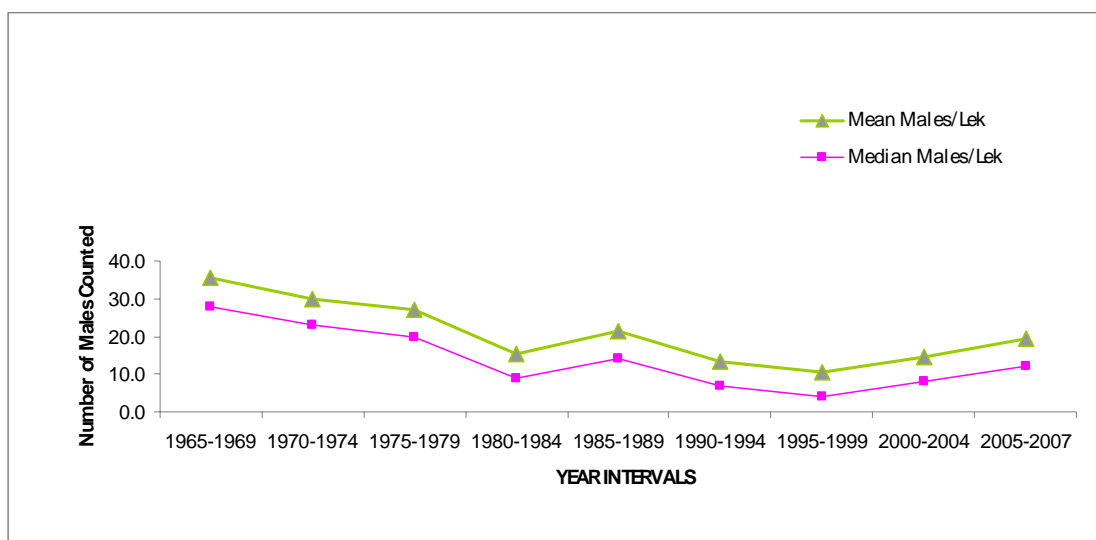
Figure 32. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in Idaho.

$$y = 3.712 - 0.106x + 0.004x^2$$

Figure 33. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in Idaho. Trends incorporate data from both active and inactive leks.

Montana. Data from 459 individual leks contributed to the trend analysis for Montana (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased 1,523% over the assessment period, from 13 in 1965-1969 to 211 in 2005-2007 (Fig. 34). Average maximum males per lek and median maximum males per lek varied over time and decreased slightly from the earliest (1965-1969) to the latest (2005-2007) analysis periods (Fig. 35). Overall, lek size decreased from 28.0 males per lek to 25.5 males per lek (Fig. 35). Trend analysis showed a measurable long-term decrease (Fig. 36) but detectable trends could not be identified for the 1965-85 or 1986-2007 analysis periods (Table 2). Leks in Montana showed substantial variation in trends in male counts (SD(β_1) = 0.205, SD(β_2) = 0.004).

Figure 34. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in Montana.
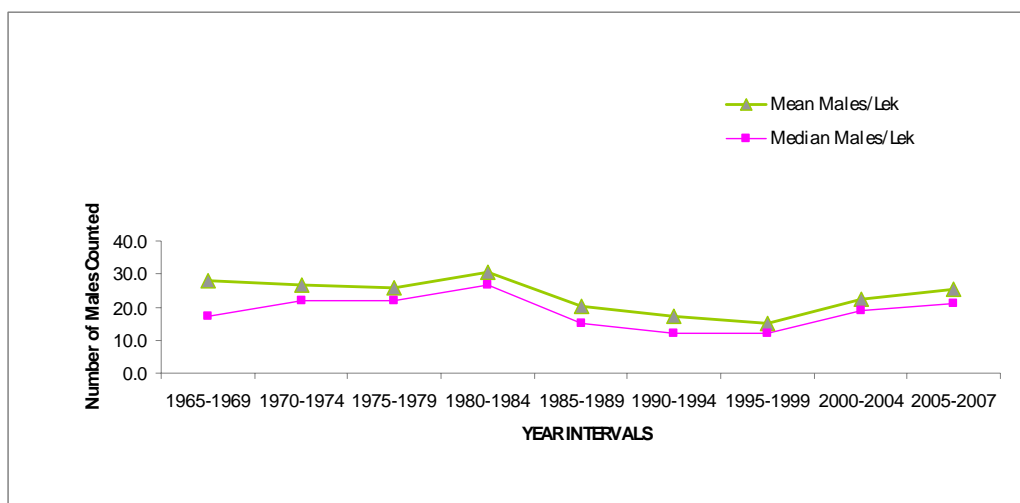
Figure 35. The mean and median maximum number of males counted on leks during time intervals from 1965-2007 in Montana.
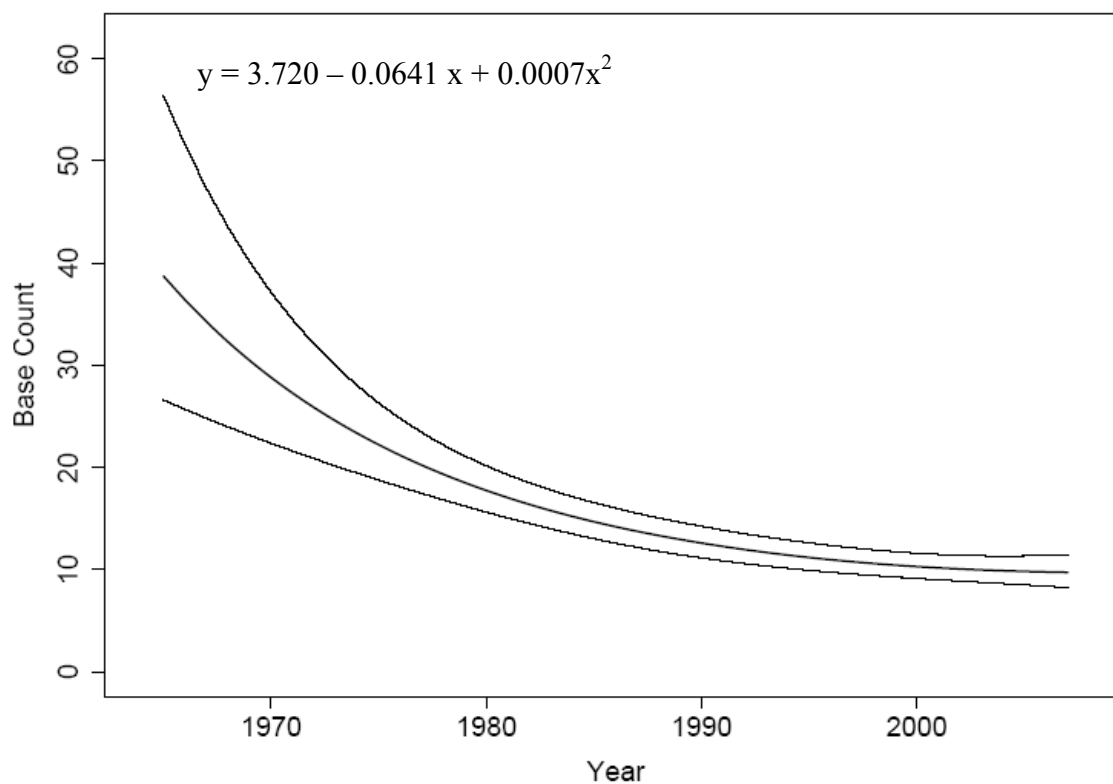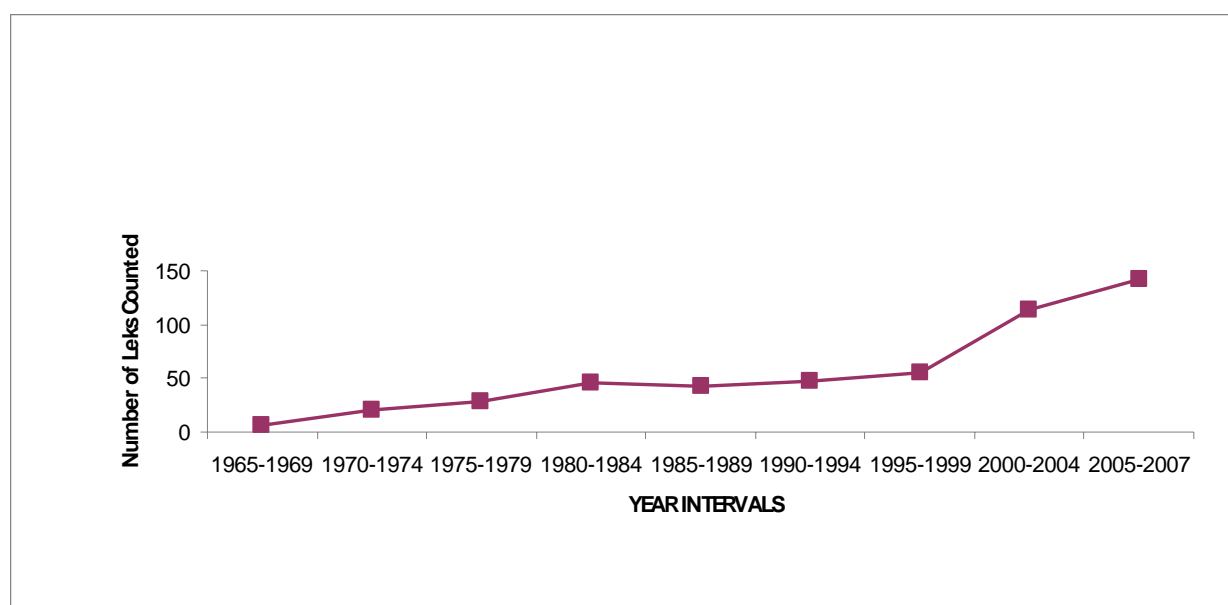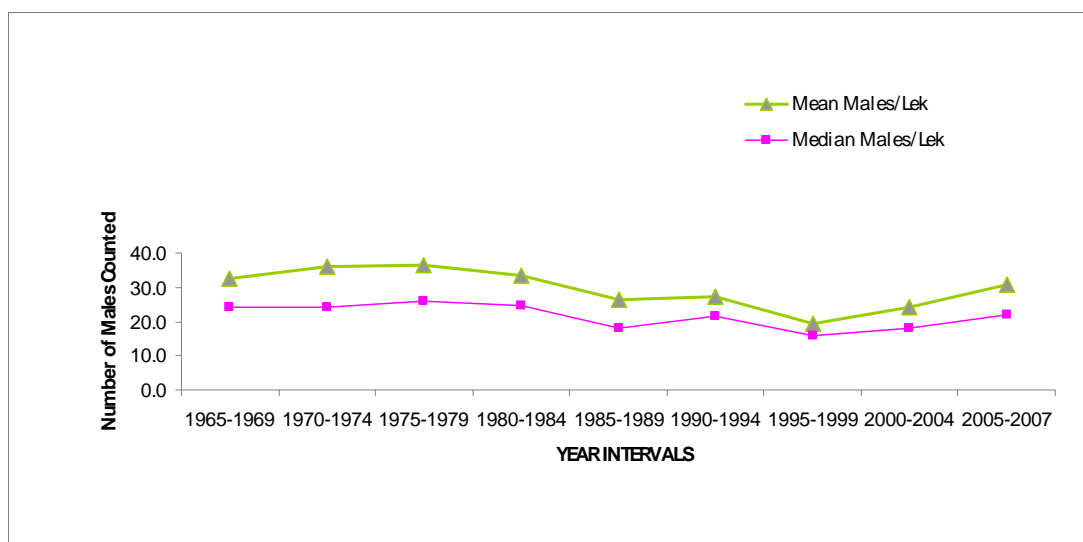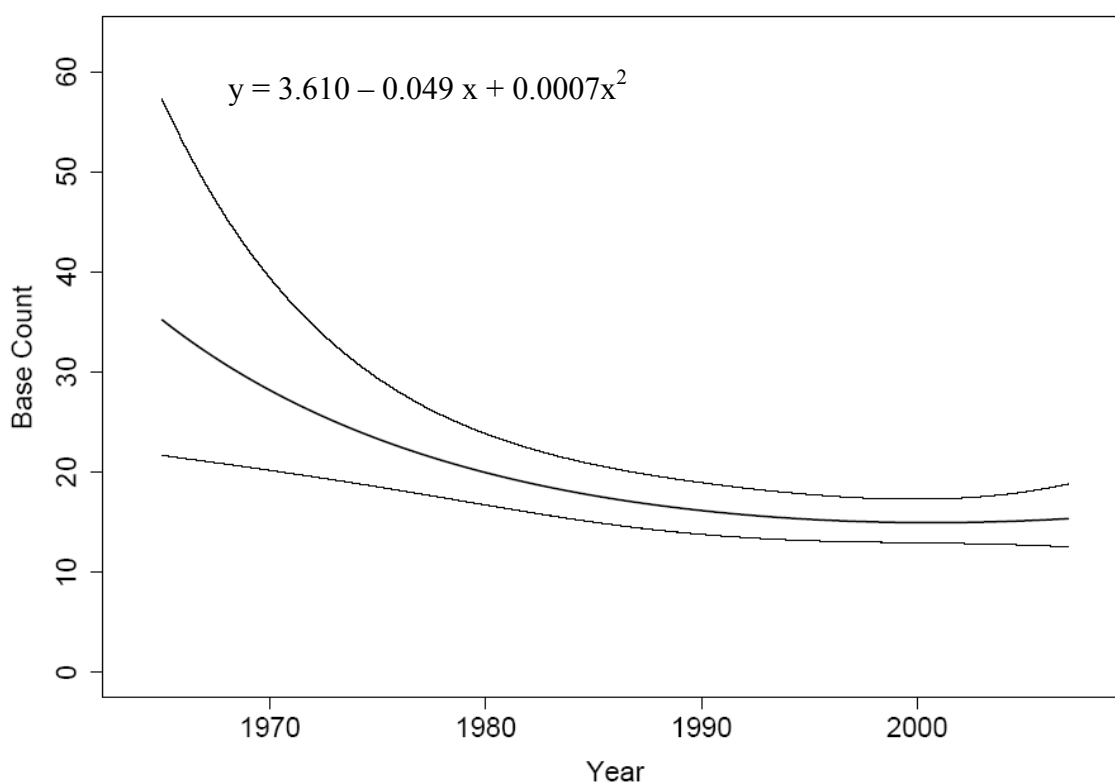

$$y = 3.720 - 0.0641 x + 0.0007x^2$$

Figure 36. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in Montana. Trends incorporate data from both active and inactive leks.

Nevada. Data from 162 individual leks contributed to the trend analysis for Nevada

(Table 2). The number of leks counted that met criteria for inclusion in the trend analysis

increased 2,283% over the assessment period, from 6 in 1965-1969 to 143 in 2005-2007 (Fig.

37). Average maximum males per lek and median maximum males per lek varied over time and

declined slightly from the early (1965-1989) to the late (2005-2007) analysis periods (Fig. 38).

Overall, lek size decreased from 32.6 lek to 30.7 males per lek (Fig. 38). Trend analysis showed

a measurable long-term decrease (Fig. 39) but detectable trends could not be identified for the

1965-85 or 1986-2007 analysis periods (Table 2). Leks in Nevada showed substantial variation

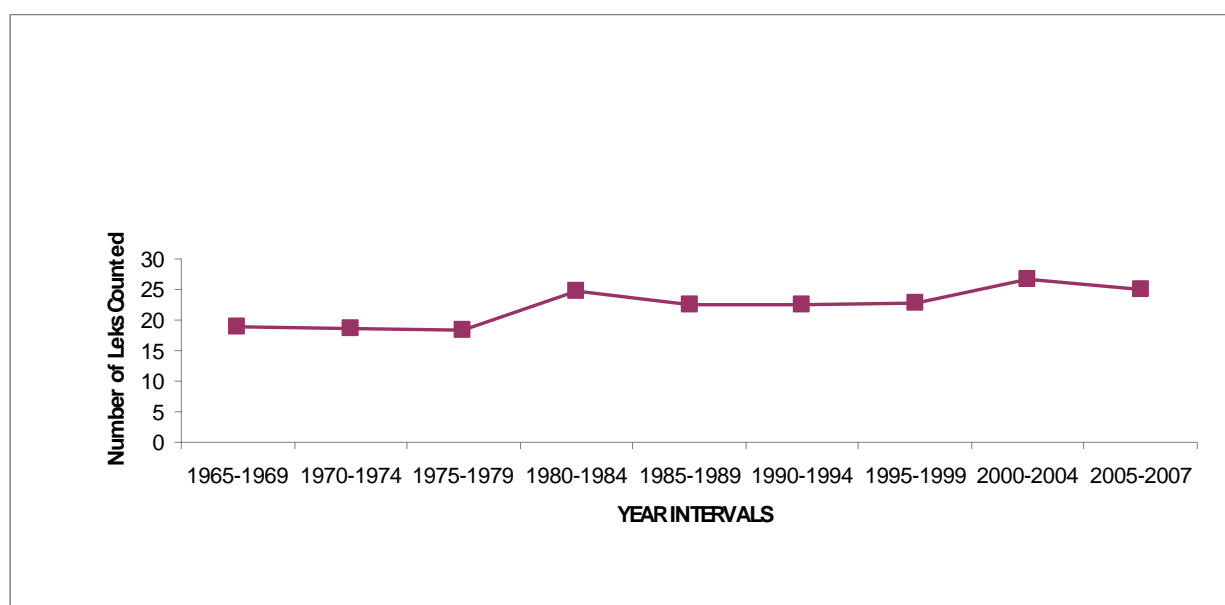in trends in male counts ($SD(\beta_1) = 0.16$, $SD(\beta_2) = 0.003$).

Figure 37. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-

2007, in Nevada.

Figure 38. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in Nevada.

$$y = 3.610 - 0.049\ x + 0.0007x^2$$

Figure 39. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in Nevada. Trends incorporate data from both active and inactive leks.

North Dakota. Data from 38 individual leks contributed to the trend analysis for North

Dakota (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis

increased 32% over the assessment period, from 19 in 1965-1969 to 25 in 2005-2007 (Fig. 40).

Average maximum males per lek and median maximum males per lek varied over time and

decreased from the earliest (1965-1969) to the latest (2005-2007) analysis periods (Fig. 41).

Overall, mean number of males per lek decreased from 13.4 males per lek to 7.7 males per lek

(Fig. 41). Trend analysis showed a measurable long-term decrease (Fig. 42) but detectable

trends could not be identified for the 1965-85 or 1986-2007 analysis periods (Table 2). Leks in

North Dakota showed less overall variation in trends in male counts compared to other states

$(SD(\beta_1) = 0.0019, SD(\beta_2) = 0.0019)$.

Figure 40. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-
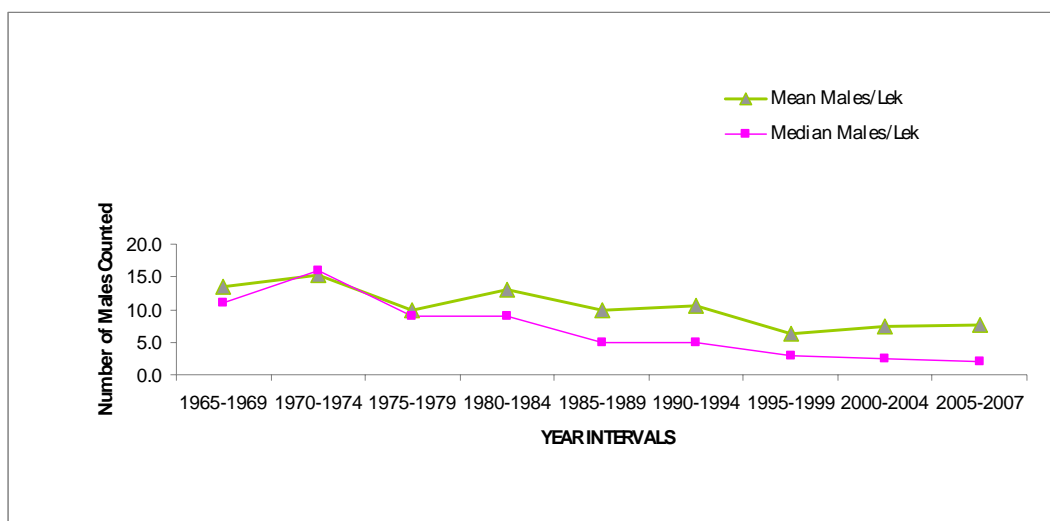
2007, in North Dakota.

Figure 41. The mean and median maximum number of males counted on leks during time intervals from 1986-2007 in North Dakota.
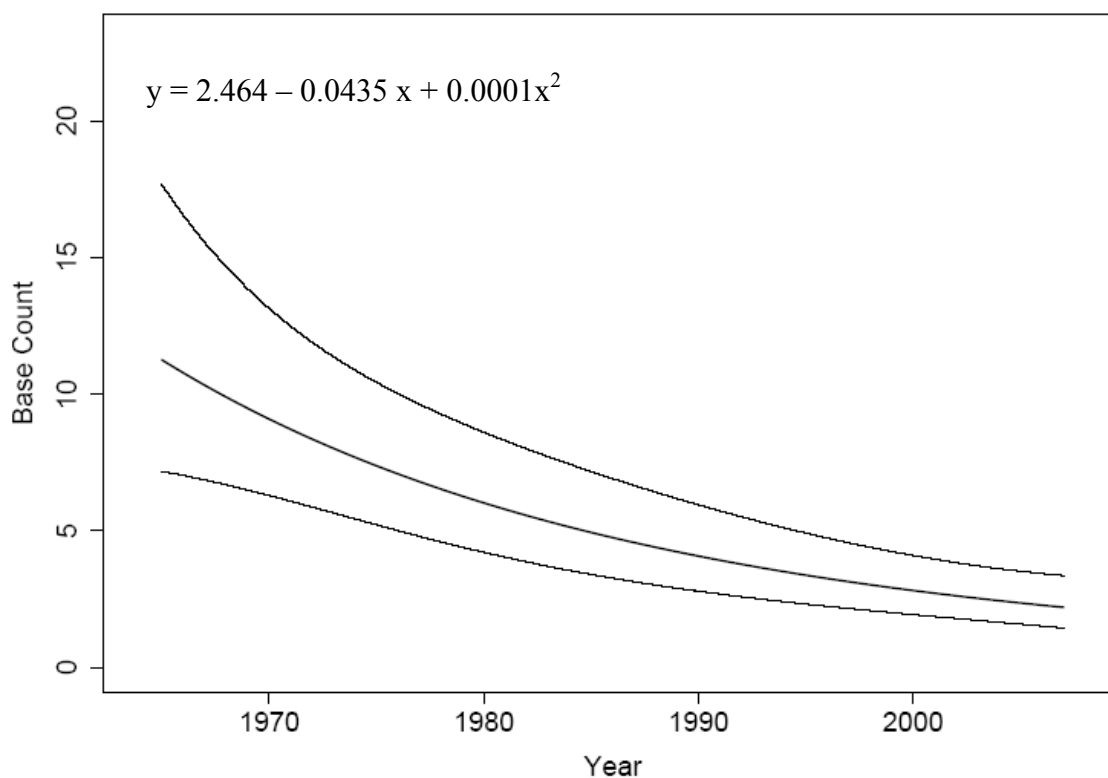

$$y = 2.464 - 0.0435\,x + 0.0001x^2$$

Figure 42. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in North Dakota. Trends incorporate data from both active and inactive leks.

Oregon. Data from 349 individual leks contributed to the trend analysis for Oregon (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased 1,076% over the assessment period, from 21 in 1965-1969 to 247 in 2005-2007 (Fig. 43). Average maximum males per lek and median maximum males per lek varied over time and decreased slightly from the early (1965-1989) to the late (2005-2007) analysis periods (Fig. 44). Overall, lek size decreased from 20.1 lek to 18.9 males per lek but there was some increase from 1990-94 to 2005-07 (Fig. 44). Trend analysis showed a measurable decrease for the long-term (Fig. 45) and 1986-2007 period but no detectable trend could be identified for the 1965-85 analysis period (Table 2). Leks in Oregon showed substantial variation in trends in male counts $(SD(\beta_1) = 0.29, SD(\beta_2) = 0.005)$.
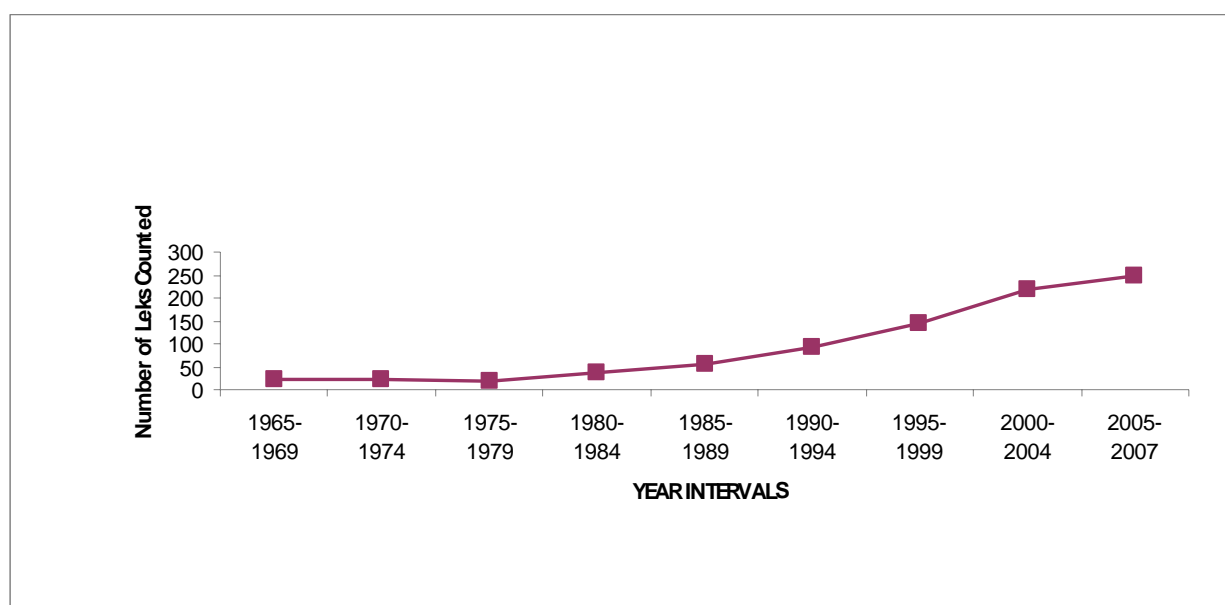

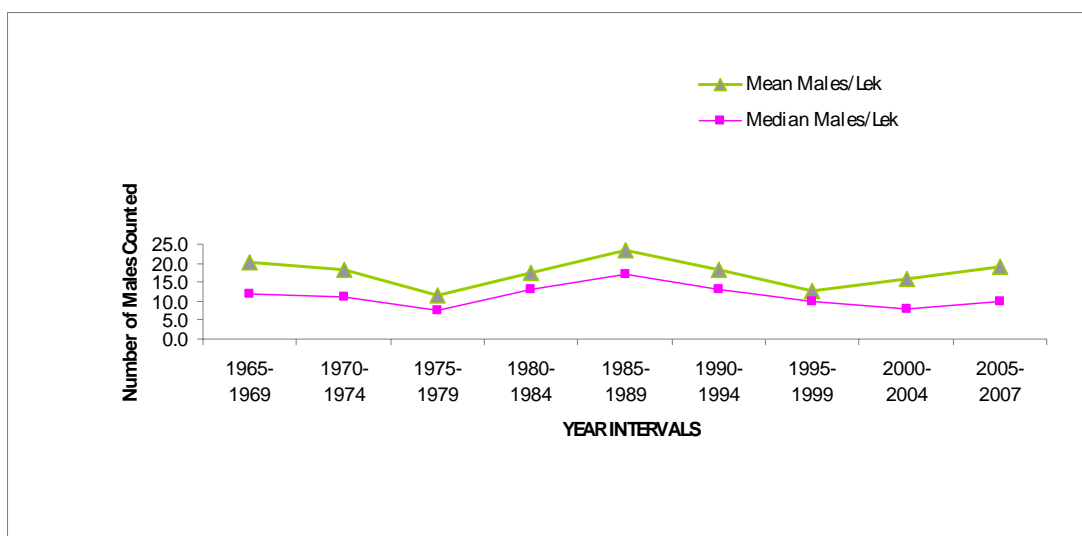Figure 43. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in Oregon.

Figure 44. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in Oregon.
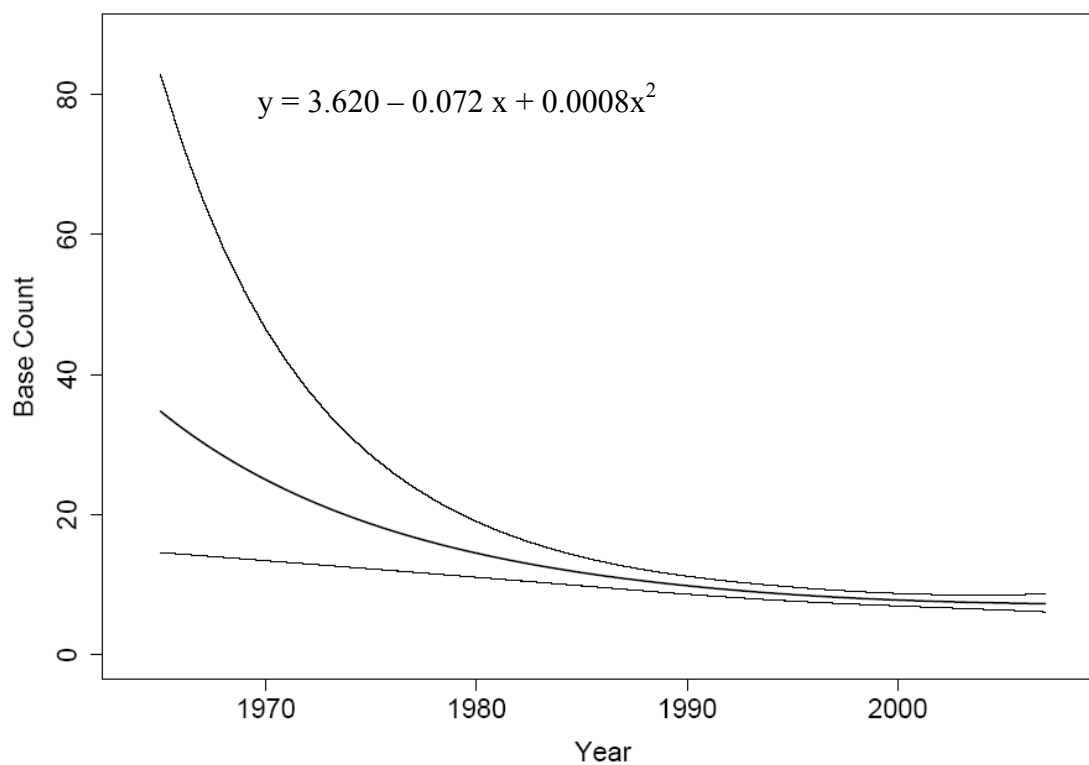

$$y = 3.620 - 0.072\,x + 0.0008x^2$$

Figure 45. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in Oregon. Trends incorporate data from both active and inactive leks.

South Dakota. Data from 19 individual leks contributed to the trend analysis for South

Dakota (Table 2). Lek-count data prior to 1989 in South Dakota were not used in this analysis

because discrepancies in the database could not be resolved in the time frame allotted for

analysis. The number of leks counted that met criteria for inclusion in the trend analysis

increased 1,700% over the assessment period, from 1 in 1989 to 18 in 2005-2007 (Fig. 46).

Average maximum males per lek and median maximum males per lek varied over time and

increased slightly between the periods from 1989 and 2005-2007 (Fig. 47). The mean lek size

increased from 17.7 per lek to 23.2 males per lek (Fig. 47). No detectable trend could be

identified for the 1989-2007 analysis period (Table 2, Fig. 48). Leks in South Dakota showed

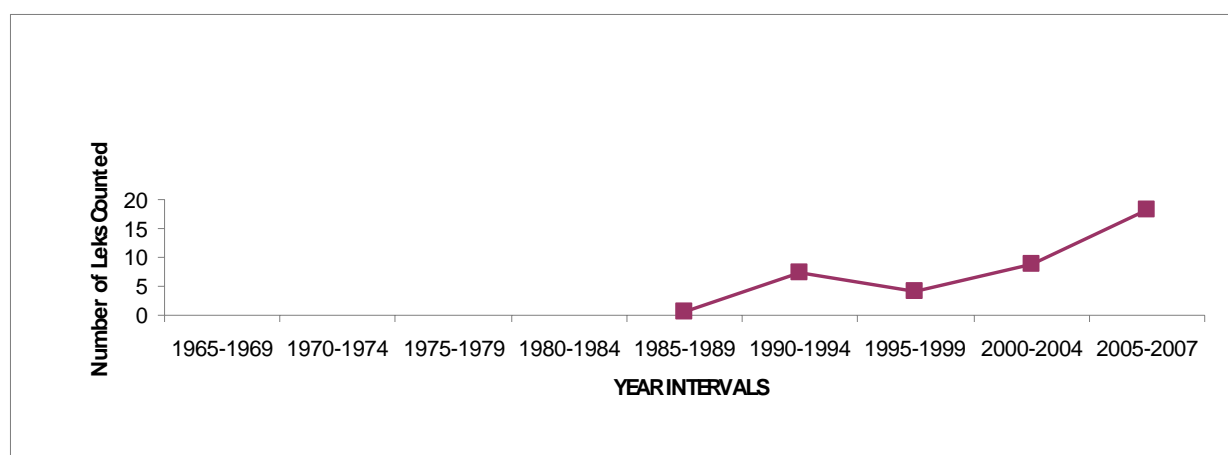some variation in male count trends (SD(β_1) = 0.055, SD(β_2) > 0.0001).

Figure 46. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1989-
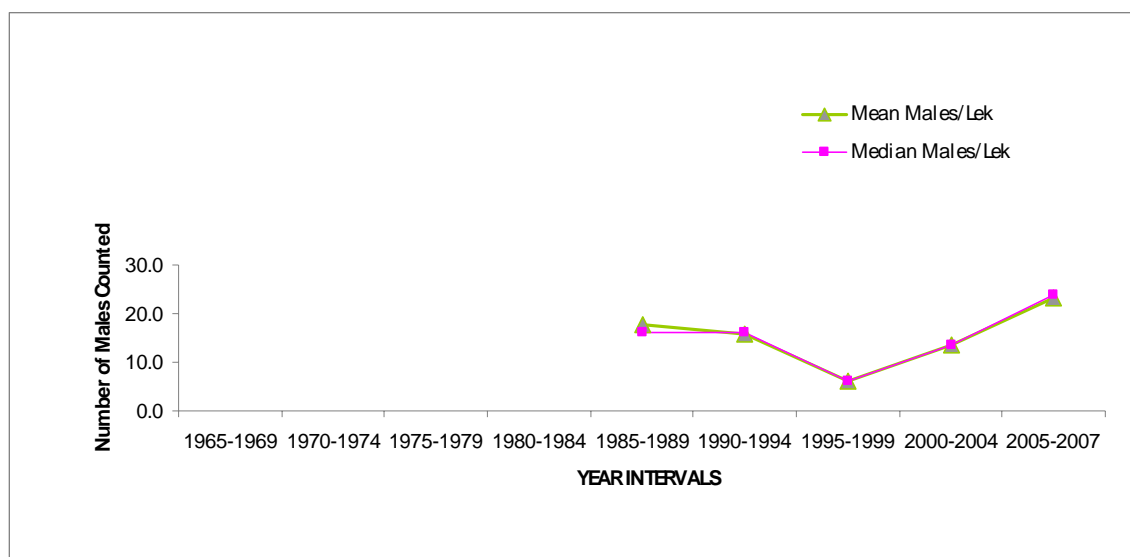
2007, in South Dakota.

Figure 47. Mean and median maximum number of males counted per lek during time intervals from 1989-2007 in South Dakota.

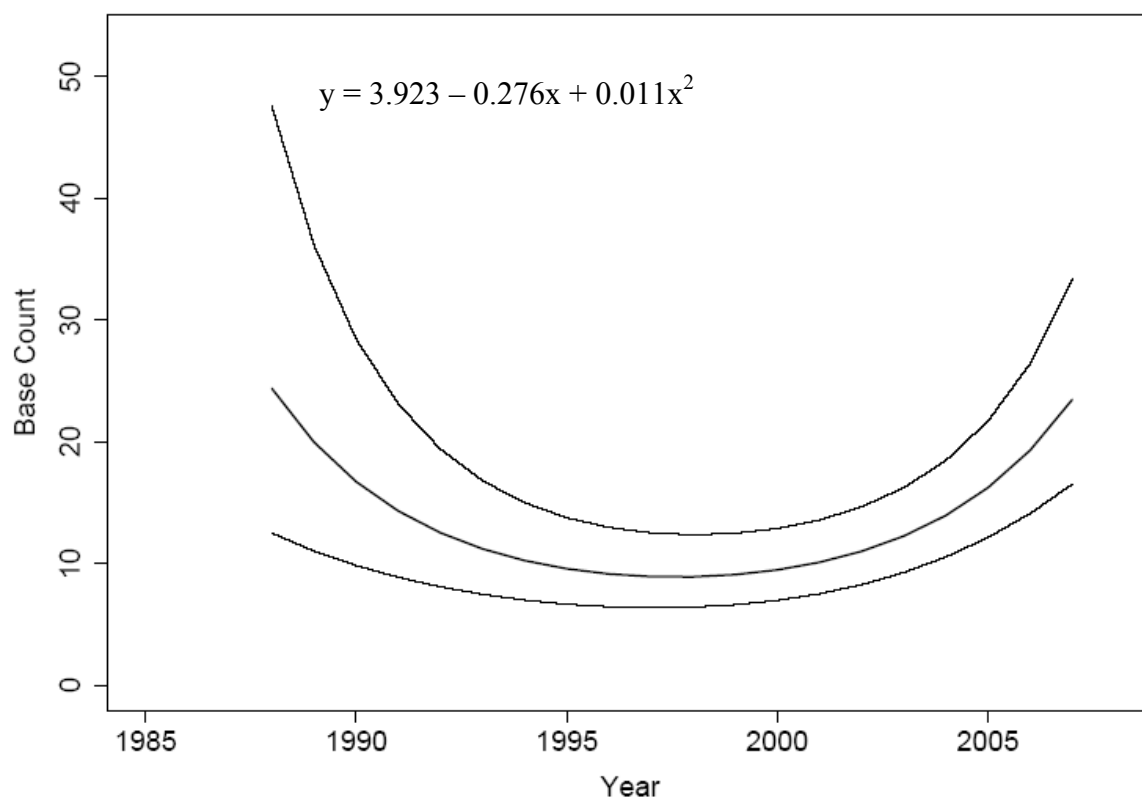$$y = 3.923 - 0.276x + 0.011x^2$$

Figure 48. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1989-2007 in South Dakota.

Utah. Data from 249 individual leks contributed to the trend analysis for Utah (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased 389% over the assessment period, from an average of 36 during 1965-1969 to an average of 176 during 2005-2007 (Fig. 49). Average males maximum per lek and median maximum males per lek varied over time but decreased somewhat from 1965-1969 to 1980-84 while increasing slightly during the later part of analysis period (Fig. 50). Overall, lek size showed little change from 1965 (25.1 males/lek) to 2007 (24.5 males per lek) and median males per lek showed the same pattern (Fig. 50). Trend analysis showed a measurable decrease for the long-term (Fig. 51) and 1965-1985 period but no detectable trend could be identified for the 1986-2007 analysis period (Table 2). Leks in Utah showed substantial variation in trends in male counts ($SD(\beta_1) = 0.13$, $SD(\beta_2) = 0.003$).
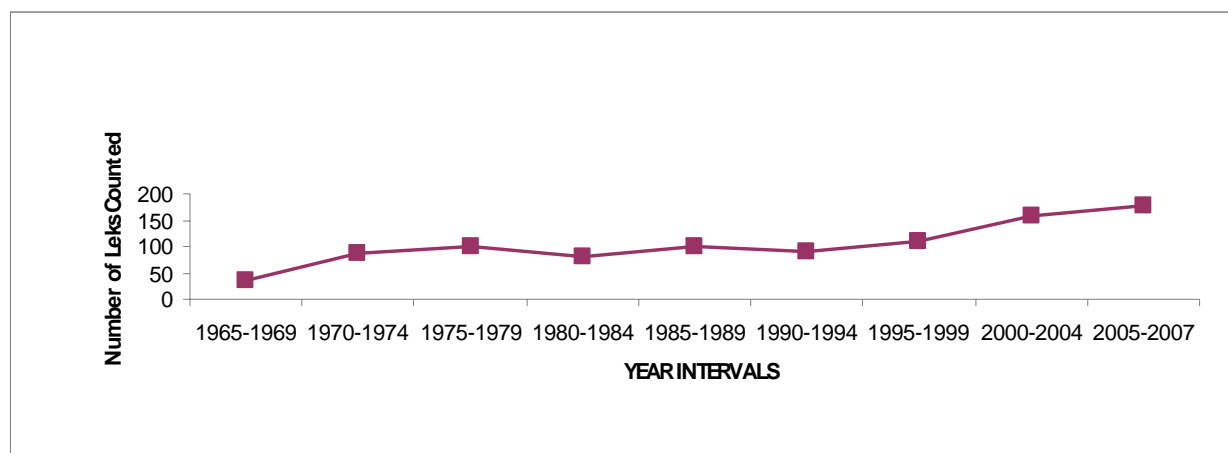

Figure 49. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in Utah.
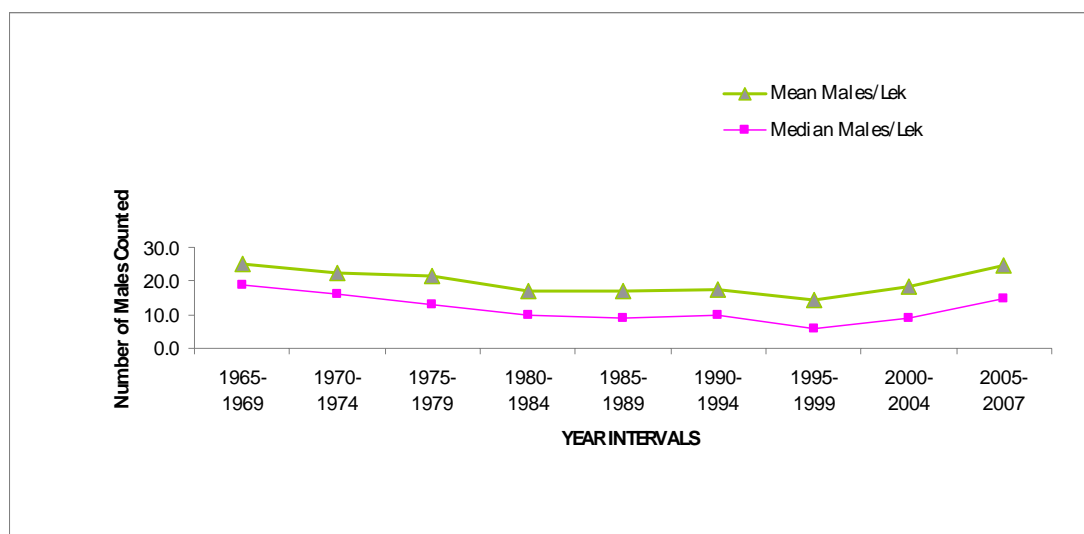
Figure 50. Mean and median maximum number of males counted per lek during time intervals from 1965-2007 in Utah.

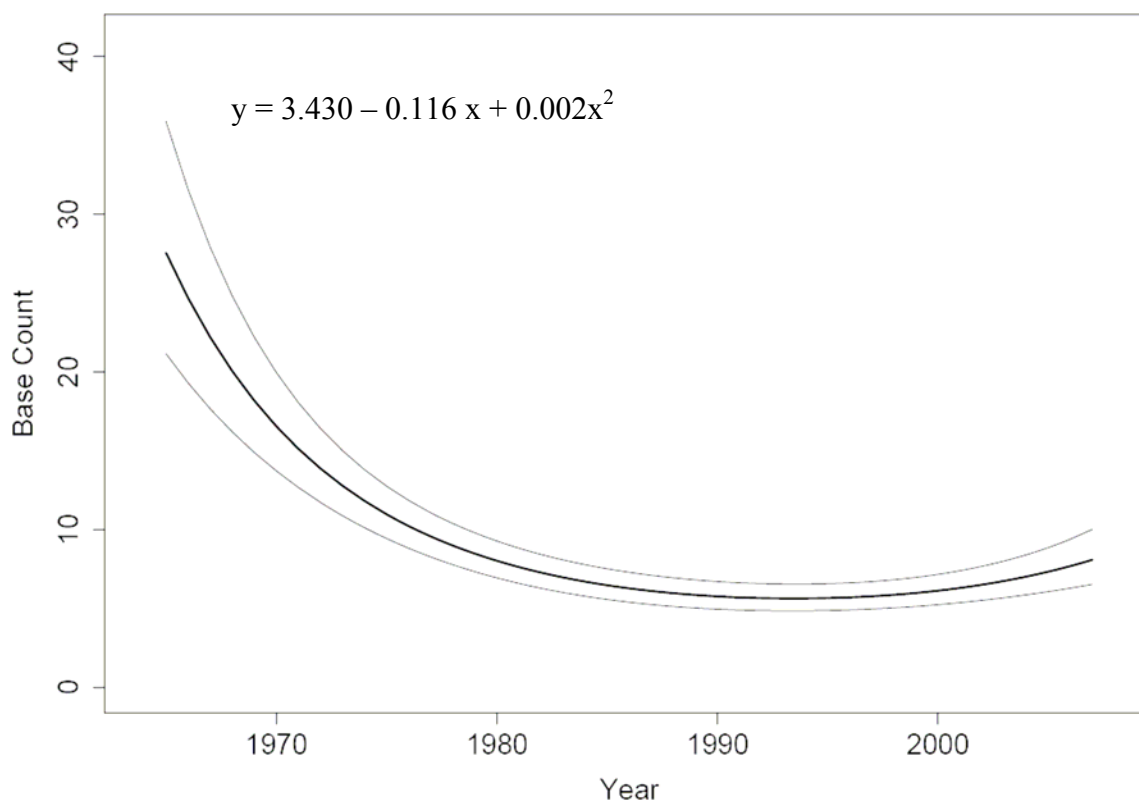
$$y = 3.430 - 0.116 \, x + 0.002x^2$$

Figure 51. The trend and the 95% confidence intervals represent a fixed effect change in the male count at the base level of the linear model, 1965-2007 in Utah. Trends incorporate data from both active and inactive leks.

Washington. Data for Washington are the same as those for MZ-VI and are in the earlier section.

Wyoming. Data from 1,108 individual leks contributed to the trend analysis for Wyoming (Table 2). The number of leks counted that met criteria for inclusion in the trend analysis increased over the assessment period by 2,159%, from 32 in 1965-1969 to 723 in 2005-2007 (Fig. 52). Average maximum males per lek and median maximum males per lek consistently declined from 1965-1969 to 1990-1994 and increased slightly between the period from 1994-1999 and 2000-2004. Both the mean and median males/lek increased sharply in the last period of record (2005-2007), approaching values seen in the 1970's but still fell short of the values reported for the 1965-1969 period (Fig. 53). Overall, lek size decreased from 49.1 per lek in 1965-1969 to a low of 19.9 males per lek in 1990-1994 and increased to 37.9 in 2005-2007 (Fig. 53). Trend analysis showed a measurable decrease for the long-term (Fig. 54) and 1965-1985 period but no detectable trend could be identified for the 1986-2007 analysis period (Table 2). Leks in Wyoming showed substantial variation in trends in male counts ($SD(\beta_1) = 0.241$, $SD(\beta_2) = 0.005$).
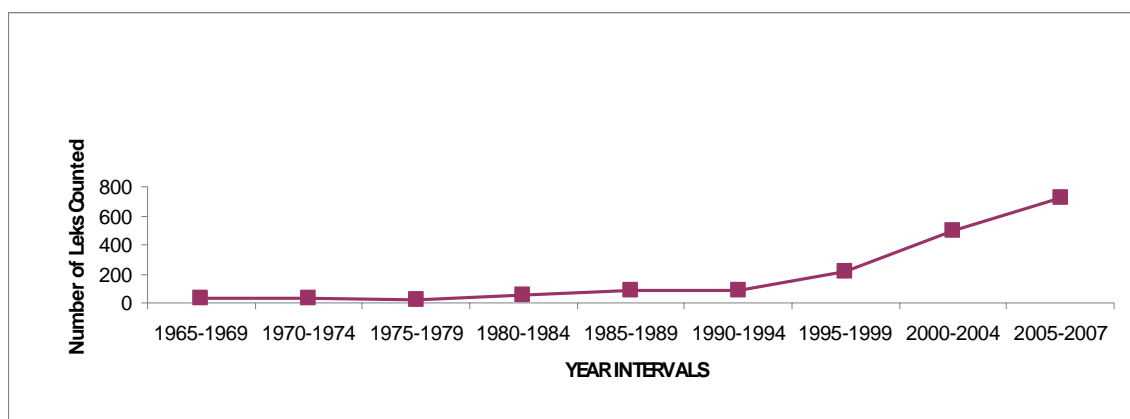

Figure 52. Number of greater sage-grouse leks monitored annually in each 5-year interval, 1965-2007, in Wyoming.
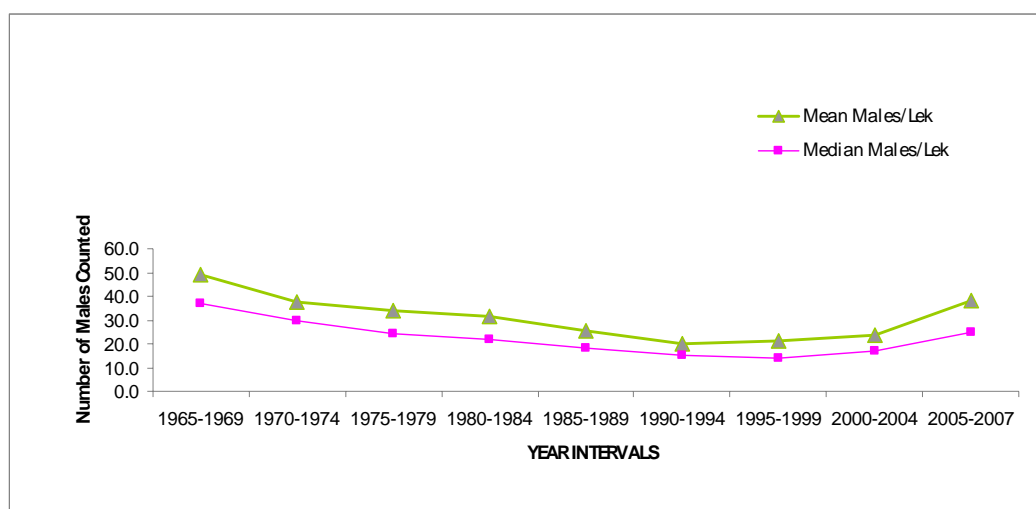
Figure 53. Mean and median maximum number of males counted per lek during time intervals from 1965 to 2007 in Wyoming.
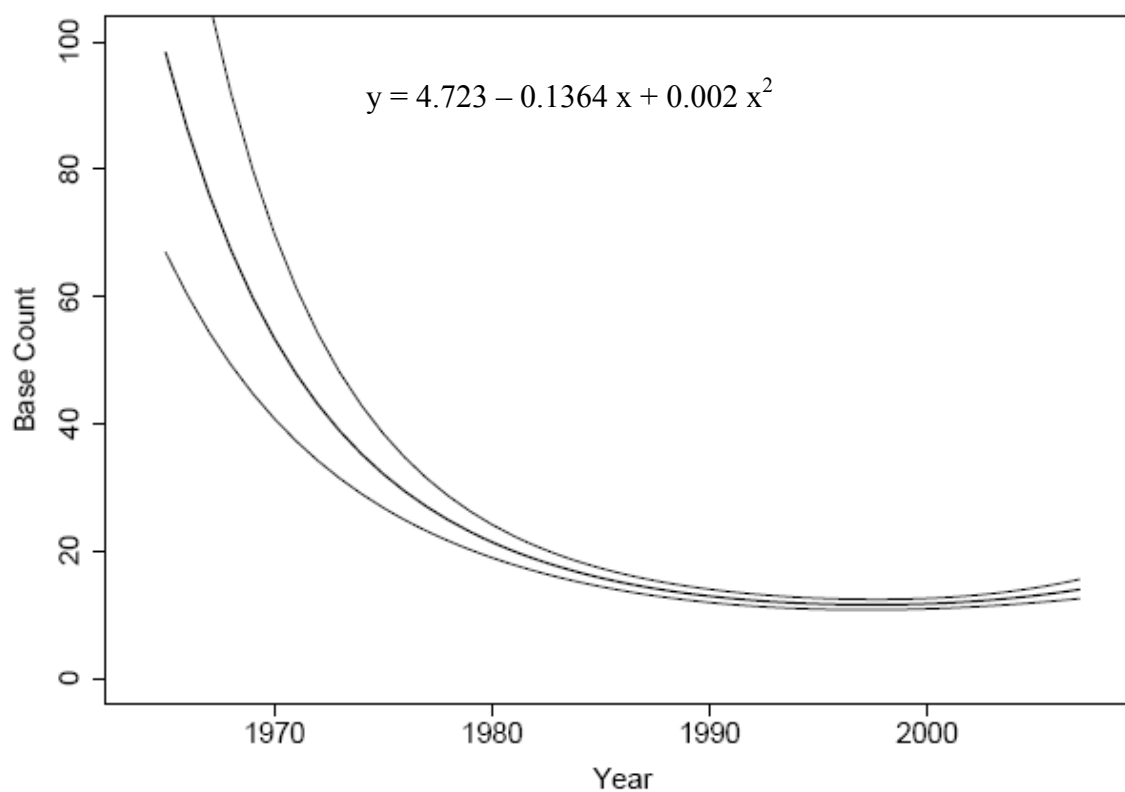

$$y = 4.723 - 0.1364 x + 0.002 x^2$$

Figure 54. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model, 1965-2007 in Wyoming. Trends incorporate data from both active and inactive leks.

Current state analysis vs. 2004 analysis

Our findings are generally similar to those of Connelly et al. (2004) that indicated a long-term range-wide decline of 2.0% per year and also reported that the greatest portion of the decline occurred from the mid-1960s to the mid 1980s. When we compared the results state-by-state we found additional similarities (Fig. 55). In most cases, our current analyses indicated larger declines than those reported by Connelly et al. (2004). The current analyses suggested that long-term declines were considerably greater in Idaho, Montana, and Utah while the increase in Colorado was lower than the increase reported by (Connelly et al. 2004).
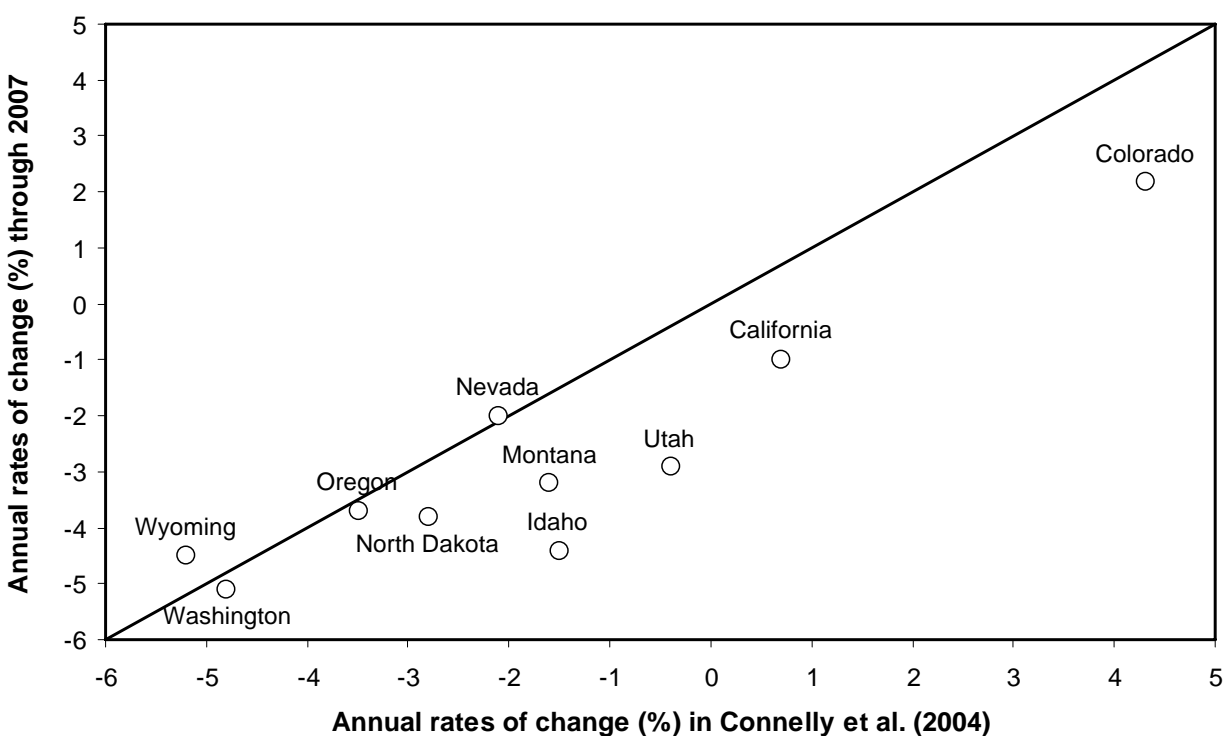

Figure 55. Comparison of annual rates of change from the current study (1965-2007) and the previous study (1965-2003, Connelly et al. 2004). Data for Colorado in Connelly et al. (2004) only included 1985-2003 to make the analysis more similar with the current study. South Dakota was not included because of insufficient data in Connelly et al. (2004). The diagonal line represents the relationship that would be present if the values for the 2 studies were identical.

DISCUSSION

Many assumptions and potential sources of error limit inferences that can be made from the data presented in this report. First, because the data are counts with no measure of detection probability and no probability-based sampling design, trends refer only to the maximum male count of sampled leks. Consequently, statistical inference does not extend to sage-grouse population size. Second, increasing count effort over time, especially in number of counts per year increases the chance of observing an unusually high count. This may have biased trends upward, particularly during the most recent time period (1986-2007). Third, the lack of a probability-based sample resulted in leks only being added to the sample after grouse were detected, and larger leks may have been more likely to be detected and counted than smaller leks. This presents the potential for a negative bias in the trend estimate. We lack data to evaluate these potential biases and therefore we had to make assumptions in order to proceed with any analysis. We chose the most credible assumptions we could given the data and did our best to define those and present the results in light of the assumptions.

Linear mixed-effects models provide more pieces of information about the data than a simple linear model and therefore require more interpretation. First, the mixed-effects models provide a standard error (SE) that measures the precision of the parameter estimate. The SEs in our analysis are small at the range, state, and management zone levels because of the large sample size of leks and counts. Second, the mixed-effects models provide a standard deviation (SD) for the parameter estimates. The SD measures the statistical population-level variation, in this case the among-lek variation. These analyses show very large SDs, reported as 'substantial' in the results. The SDs were often several times larger than the parameter estimates themselves suggesting the trends at the lek level vary considerably. An example of this variation for

Colorado leks is given in Figure 56. Fourth, the shape of the quadratic trend line must be examined carefully because in all cases, the shape of the "U" in the quadratic can be instructive if there was an increase in the male-count in the later analysis time-period. For example, the quadratic may be an upward-facing "U" in which the male counts decline in the early period and increase in the later period. When interpreting quadratic models both the slope of the linear and quadratic term must be considered to understand the shape of the relationship.
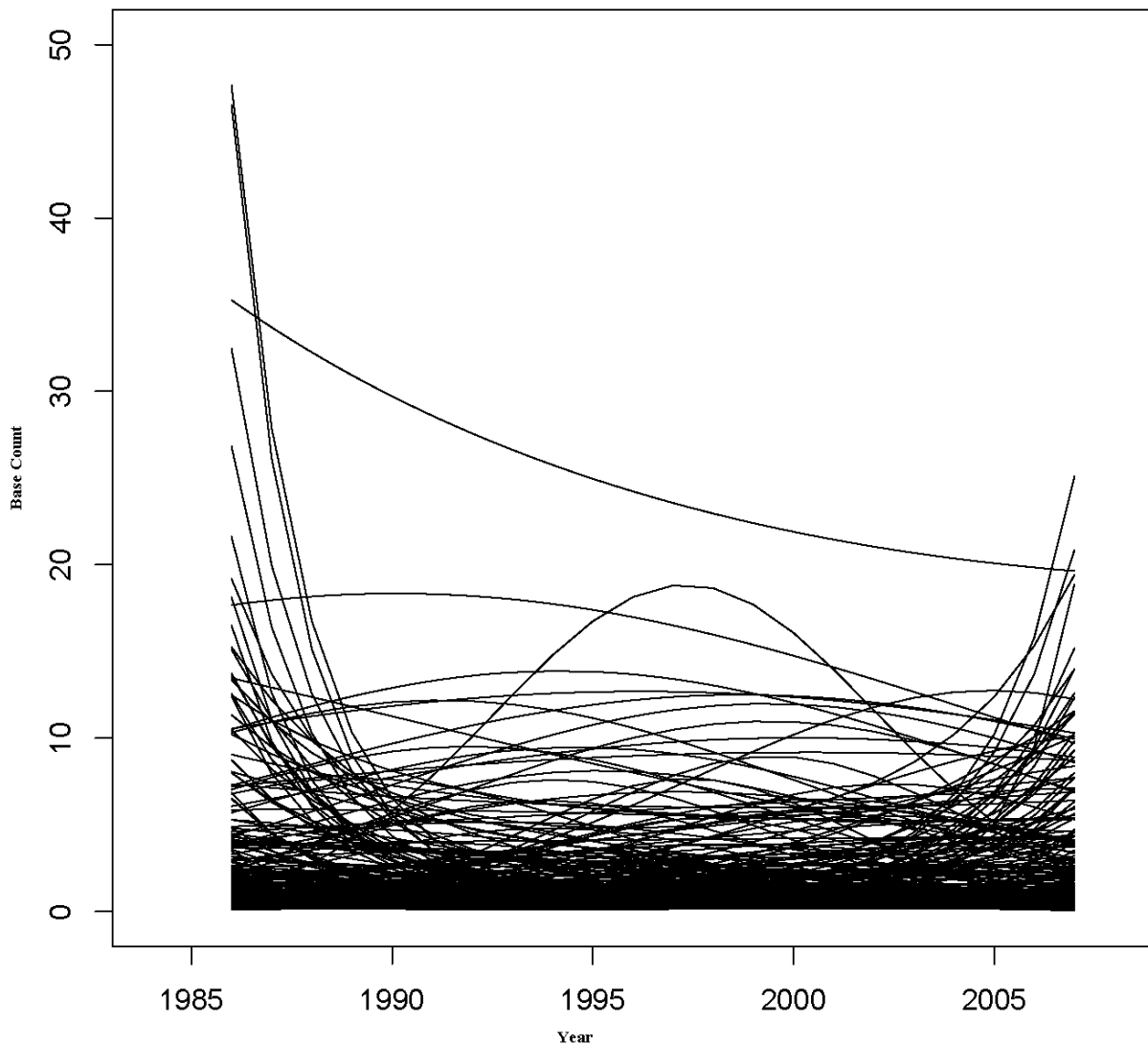

Figure 56. An example of among-lek variation in trend in Colorado showing the variation portrayed in the standard deviations.

We estimated trends in maximum male count for the entire range of sage-grouse, 7 Management Zones, 11 Western States, and 31 populations (Appendix D). Our results generally suggest a long-term decline of greater sage-grouse maximum male counts and further indicate that the greatest declines occurred from the mid-1960s to the mid-1980s. Throughout their range, lek size for this species was largely unchanged from 1965 through 2007. Nevertheless, over this same period we estimated a measurable decreasing trend of 3.1% per year, primarily due to the decline in the number of active leks. All management zones (Table 1) showed measurable declines from 1965 to 2007 and 4 of 7 management zones declined from 1965 to 1985. From 1986 to 2007, only MZ-IV (–2.0%) and MZ-V (–3.6%) had measurable declining trends, and MZ-II had a measurable increasing trend (1.5%).Eight of 9 states for which we estimated trends between 1965 and 2007 indicated measurable declining trends (range: –2 to –5% annually). Idaho, Utah, Washington, and Wyoming, for which we estimated trends for the early period (1965 to 1985), had measurable declining trends (range: –4 to –8% annually), the other 5 states had decreasing trends but were not measurably different from no-trend. California, Idaho, and Oregon had measurable declining trends (range: –3 to –5% annually) in the late period. Only Colorado had a measurable increasing trend for this period (2%).

There are numerous possible explanations for differences in results between these analyses and those of Connelly et al. (2004). For example, if the populations declined since 2003, which is at least partially supported by the data, these declines would be reflected in the current analyses. Additionally, most states have spent considerable effort since 2003 refining their databases (i.e., adjusting the definition of leks and deleting spurious observations or leks without spatial data) and these modifications may have affected the estimated rates of change. It is also clear the analytical techniques were substantially different in 2004 (Connelly et al.) than

in this current report, and these differences may have directly influenced results. Based on the sample size of leks (3,419 leks used in current study vs. 5,585 leks used in 2004 study) and maximum lek counts (34,441 counts used in current study vs. 44,155 counts used in 2004 study), the data filtering process used in this study may have removed substantial data from the analysis.

MANAGEMENT RECOMMENDATIONS

We recommend that Western Agencies continue to monitor leks as a method to assess sage-grouse population trends. Nevertheless there are three areas needing improvement: 1) establishing a range-wide lek count database that standardizes data reported across states and provinces to assist in expediting future range-wide analyses; 2) improving our understanding of the link between lek counts and population abundance; and 3) standardizing future lek monitoring across states based on a probability sampling design using area-based sampling units.

Monitoring data from all efforts should be stored in a range-wide relational database not a spreadsheet. Relational databases help to keep data better organized and minimize data input errors, which are rampant in current lek data sets (e.g., misspelled names of leks). Numerous problems were encountered in our attempts to resolve data discrepancies and to identify reliable data within each state's dataset. Based on this, we recommend that at minimum, data collected during each visit to a lek should include: (1) a unique lek ID; (2) number of males observed; (3) date; (4) start time, (5) count duration, (6) exact location information, (7) count method (ground, aerial, helicopter, etc.), (8) weather conditions, (9) observer(s), and (10) notes on how disturbances or weather influenced the count or detectability.

Garton et al. (2007) provided recommendations for improvements to lek surveys. Garton et al. (2007) suggested changing the sampling unit to an area instead of a point. They then

suggest stratifying the sage-grouse range into three strata: 1) current lek routes, 2) areas near current leks, and 3) areas far from current leks. Units would be selected probabilistically within each stratum. The Garton et al. (2007) design can be made more efficient by placing it in a dual-frame sampling approach (Haines and Pollock 1998) rather than using a stratified random sampling design. Dual-frame sampling designs fit well into situations with a long history of data collection at specific locations without a probability-based design. A dual-frame sampling scheme consists of two frames; a list frame comprised of known lek sites and an area frame consisting of all other potential sage-grouse habitat where leks are not currently known to occur. Data collected in the list frame helps maintain continuity with historic data while being in a probability-based design. Data from the area frame allow inferences to be made to the entire sage-grouse population, not just to those leks that are counted.

We support Garton et al.'s (2007) recommendation to use this multi-phase sampling of leks and suggest that its implementation be strongly considered by the Western Agencies Sage and Columbian Sharp-tailed Grouse Technical Committee. The design presented could be first implemented at a smaller scale than the entire range. For example, a subset of states (or region within a state) could implement the design before other states. This modification would require the range be stratified by state, but that would likely be desirable for state-level inference also.

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Table 1. Male-count trend by management zone (MZ) in North America as represented by a the best fit fixed effect model and the resulting statistics of the intercept, constant linear, and quadratic models, the 95% lower (LCI) and upper (UCI) 95% confidence intervals (CI) and standard deviations (SD) for the timeframe 1965 - 2007. Model selection criteria is reported as ΔAIC for the next best approximating model.

Area Year interval	Number Leks	Counts	ΔAIC	Model type	Annual trend (%)	β_0 Estimate	95% C.I.	β_1 Estimate	95% C.I.	β_2 Estimate	95% C.I.
Range-wide											
1965-2007	3419	34441	2379.4	Quadratic	-3.1%	3.520	3.157 to 3.883	-0.087	-0.100 to -0.074	0.001	0.001 to 0.002
1965-1985	1194	8232	376.0	Quadratic	-3.3%	2.810	2.579 to 3.041	0.002	-0.029 to 0.032	-0.002	-0.003 to -0.001
1986-2007	3360	30209	2382.5	Quadratic	-1.4%	2.597	2.225 to 2.969	-0.093	-0.123 to -0.063	0.003	0.002 to 0.005
MZ-I											
1965-2007	692	6205	269.1	Quadratic	-2.9%	3.478	3.144 to 3.812	-0.055	-0.082 to -0.028	0.001	0.000 to 0.001
1965-1985	254	1657	81.7	Quadratic	0.3%	2.348	1.968 to 2.727	0.073	0.014 to 0.132	-0.003	-0.005 to -0.001
1986-2007	687	4548	349.8	Quadratic	-1.3%	2.636	2.433 to 2.838	-0.055	-0.085 to -0.025	0.002	0.001 to 0.003
MZ-II											
1965-2007	1242	11795	401.1	Quadratic	-2.7%	3.818	3.440 to 4.197	-0.115	-0.140 to -0.091	0.002	0.016 to 0.002
1965-1985	280	1068	33.4	Quadratic	-3.9%	3.589	3.237 to 3.941	-0.077	-0.141 to -0.013	0.002	-0.001 to 0.004
1986-2007	1228	10727	704.9	Quadratic	1.5%	2.337	2.169 to 2.504	-0.051	-0.075 to -0.026	0.003	0.002 to 0.004
MZ-III											
1965-2007	218	4046	263.2	Quadratic	-2.2%	3.242	2.954 to 3.530	-0.070	-0.095 to -0.045	0.001	0.001 to 0.002
1965-1985	144	1464	41.4	Quadratic	-4.1%	2.707	2.248 to 3.165	0.021	-0.053 to 0.094	-0.003	-0.006 to -0.001
1986-2007	212	2582	163.3	Quadratic	-0.9%	2.653	2.417 to 2.889	-0.101	-0.136 to -0.066	0.004	0.003 to 0.005
MZ-IV											
1965-2007	852	11526	776.4	Quadratic	-3.8%	3.630	3.373 to 3.886	-0.098	-0.117 to -0.078	0.001	0.001 to 0.002
1965-1985	392	3195	199.1	Quadratic	-5.3%	2.824	2.569 to 3.078	0.021	-0.025 to 0.067	-0.003	-0.005 to 0.002
1986-2007	825	8331	931.0	Quadratic	-2.0%	2.678	2.490 to 2.866	-0.134	-0.164 to -0.105	0.005	0.004 to 0.006
MZ-V											
1965-2007	341	3735	265.3	Quadratic	-3.3%	3.612	2.806 to 4.417	-0.064	-0.117 to -0.018	0.001	-0.001 to 0.002

1965-1985	94	580	27.4	Quadratic	-1.8%	2.692	2.170 to 3.213	0.051	-0.143 to 0.040	0.002	-0.002 to 0.005
1986-2007	334	3155	150.0	Quadratic	-3.6%	3.094	2.822 to 3.367	-0.116	-0.158 to -0.073	0.003	0.002 to 0.005
MZ-VI											
1965-2007	36	807	181.9	Quadratic	-5.1%	3.846	3.317 to 4.375	-0.104	-0.169 to -0.038	0.001	-0.000 to 0.003
1965-1985	25	253	133.9	Linear	-8.1%	3.721	3.227 to 4.216	-0.085	-0.136 to -0.033		
1986-2007	36	554	44.0	Quadratic	-2.1%	2.093	1.530 to 2.657	-0.047	-0.121 to 0.028	0.001	-0.002 to 0.004
MZ-VII											
1965-2007	38	327	11.1	Quadratic	-4.3%	5.543	2.632 to 8.455	-0.275	-0.450 to -0.099	0.004	0.002 to 0.007
1965-1985	5	15	4.12	Constant	0.0%	2.212	1.450 to 2.973				
1986-2007	38	312	13.2	Quadratic	-1.3%	1.969	1.136 to 2.802	-0.152	-0.280 to -0.023	0.006	0.001 to 0.011

Table 2. Male-count trend by state in North America as represented by a the best fit fixed effect model and the resulting statistics of

the intercept, constant linear, and quadratic models, the 95% lower (LCI) and upper (UCI) 95% confidence intervals (CI) and

standard deviations (SD) for the timeframe 1965 - 2007. Model selection criteria is reported as ΔAIC for the next best approximating

model.

| State | Number | | ΔAIC | Model | Annual | β_0 | | β_1 | | β_2 | |
Year interval	Leks	Counts		type	trend (%)	Estimate	95% C.I.	Estimate	95% C.I.	Estimate	95% C.I.
California											
1965-2007	76	1150	13.3	Quadratic	-1.0%	2.404	1.795 to 3.012	0.033	-0.015 to 0.081	-0.001	-0.002 to 0.000
1965-1985	32	328	0.71	Linear	-3.9%	2.737	2.160 to 3.313	-0.039	-0.072 to -0.006		
1986-2007	75	822	14.1	Quadratic	-4.8%	3.229	2.712 to 3.747	-0.098	-0.017 to -0.025	0.002	-0.001 to 0.005
Colorado											
1986-2007	295	4169	258.3	Quadratic	2.2%	1.473	1.221 to 1.726	-0.026	-0.067 to 0.014	0.003	0.001 to 004
Idaho											
1965-2007	628	8930	624.7	Quadratic	-4.4%	3.716	3.418 to 4.013	-0.106	-0.013 to 0.083	-0.001	-0.002 to 0.001
1965-1985	324	2517	187.9	Linear	-6.7%	2.940	2.653 to 3.227	-0.004	-0.049 to 0.057		
1986-2007	601	6413	855.1	Quadratic	-2.9%	2.852	2.649 to 3.055	-0.182	-0.216 to -0.149	0.007	0.001 to 0.008
Montana											
1965-2007	459	4606	211.9	Quadratic	-3.2%	3.720	3.324 to 4.116	-0.064	-0.095 to -0.033	0.001	0.000 to 0.001
1965-1985	176	1221	41.5	Quadratic	1.4%	2.306	1.699 to 2.913	0.086	-0.001 to 0.173	-0.003	-0.006 to 0.000
1986-2007	459	3385	234.4	Quadratic	-1.1%	2.794	2.573 to 3.015	-0.075	-0.108 to -0.042	0.003	0.002 to 0.004
Nevada											
1965-2007	162	2229	187.3	Quadratic	-2.0%	3.610	3.099 to 4.121	-0.049	-0.088 to -0.011	0.001	0.000 to 0.001
1965-1985	80	554	62.9	Linear	-1.1%	3.200	2.801 to 3.599	-0.012	-0.037 to 0.014		
1986-2007	162	1675	104.0	Quadratic	-1.5%	3.238	2.988 to 3.488	-0.085	-0.124 to -0.047	0.003	0.001 to 0.005
North Dakota											
1965-2007	38	950	31.2	Quadratic	-3.8%	2.464	1.997 to 2.930	-0.043	-0.083 to -0.004	0.000	-0.001 to 0.001
1965-1985	34	427	23.6	Quadratic	-3.6%	2.446	2.029 to 2.863	-0.039	-0.123 to 0.044	0.000	-0.004 to 0.004
1986-2007	36	523	96.0	Quadratic	-3.8%	1.708	1.229 to 2.188	-0.047	-0.129 to 0.036	0.000	-0.003 to 0.004

Oregon											
1965-2007	349	3781	227.1	Quadratic	-3.7%	3.620	2.714 to 4.525	-0.072	-0.128 to -0.015	0.001	-0.001 to 0.002
1965-1985	73	520	22.1	Quadratic	-2.3%	2.783	2.197 to 3.370	-0.094	-0.193 to 0.004	0.000	-0.001 to 0.001
1986-2007	343	3261	143.0	Quadratic	-3.4%	2.889	2.610 to 3.168	-0.104	-0.147 to -0.061	0.003	0.001 to 0.005
South Dakota											
1986-2007	19	160	15.6	Quadratic	0.8%	3.923	2.979 to 4.866	-0.276	-0.401 to 0.151	0.011	0.007 to 0.015
Utah											
1965-2007	249	4325	342.7	Quadratic	-2.9%	3.430	3.151 to 3.708	-0.116	-0.140 to -0.091	0.002	0.002 to 0.003
1965-1985	157	1616	225.6	Linear	-6.4%	3.077	2.842 to 3.312	-0.066	-0.082 to -0.049		
1986-2007	239	2709	282.2	Quadratic	1.1%	2.110	1.832 to 2.387	-0.090	-0.134 to -0.045	0.004	0.003 to 0.006
Washington											
1965-2007	36	807	180.9	Quadratic	-5.1%	3.846	3.317 to 4.375	-0.104	-0.169 to -0.038	0.001	-0.000 to 0.003
1965-1985	25	253	133.9	Linear	-8.1%	3.721	3.227 to 4.216	-0.085	-0.136 to -0.033		
1986-2007	36	554	44.0	Quadratic	-2.1%	2.093	1.530 to 2.657	-0.047	-0.121 to 0.028	0.001	-0.002 to 0.004
Wyoming											
1965-2007	1108	7334	372.4	Quadratic	-4.5%	4.723	4.320 to 5.126	-0.136	-0.164 to -0.109	0.002	0.002 to 0.003
1965-1985	292	796	12.9	Quadratic	-4.3%	3.714	3.354 to 4.075	-0.068	-0.136 to -0.001	0.001	-0.002 to 0.004
1986-2007	1095	6538	282.4	Quadratic	-0.6%	2.904	2.712 to 3.096	-0.080	-0.107 to -0.052	0.003	0.002 to 0.004

APPENDIX A: DISTRIBUTION OF SAGE-GROUSE IN NORTH AMERICA

Fig. A. Current distribution of sage-grouse and pre-settlement distribution of potential habitat in North America (Schroeder et al. 2004). For reference, Gunnison sage-grouse in southeastern Utah and southwestern Colorado are shown (after Connelly et al. 2004)
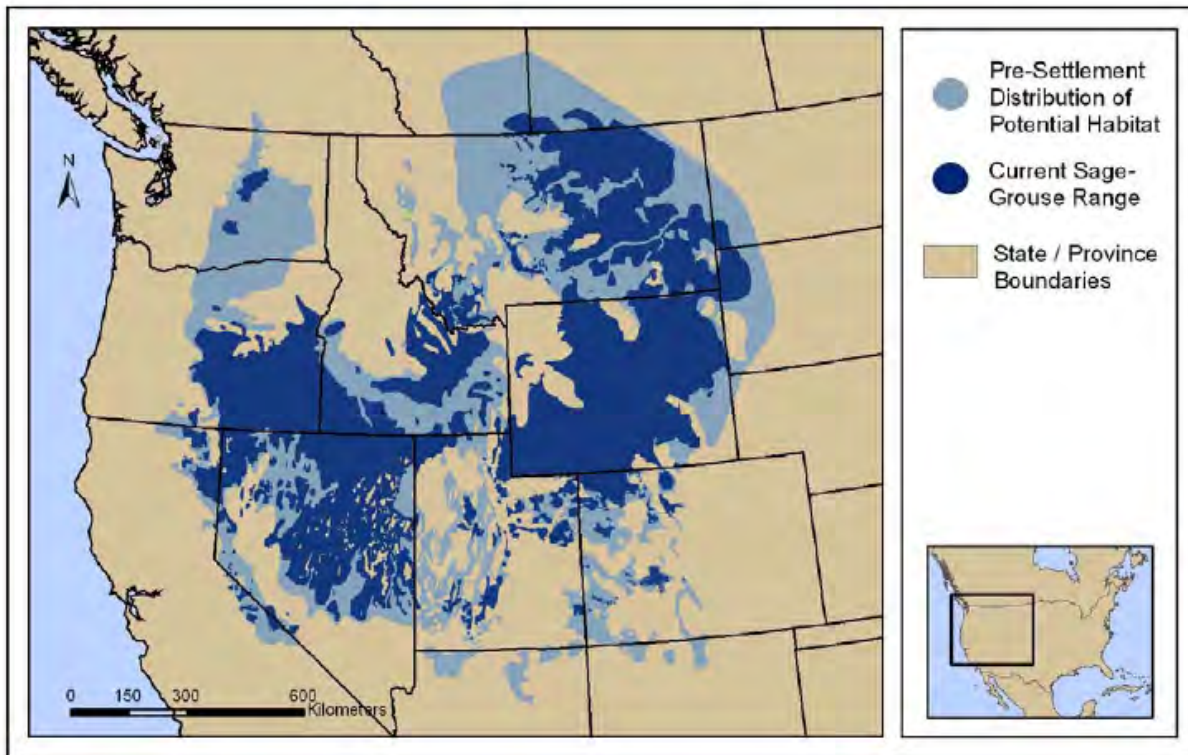
APPENDIX B: SAGE-GROUSE MANAGEMENT ZONES IN NORTH AMERICA

Fig. B. Sage-grouse management zones and populations used in trend analyses. Subpopulations are depicted illustration purposes, but were not analyzed in this report (After Stiver et al. 2006).
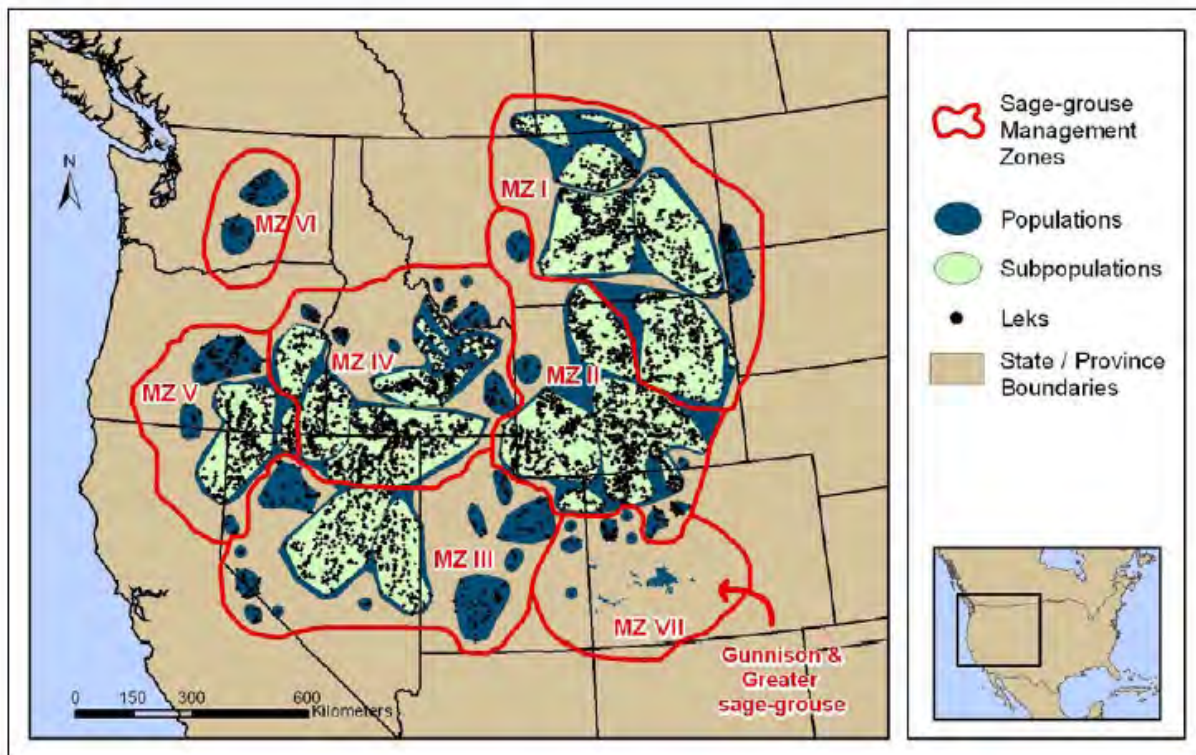
APPENDIX C: SAGE-GROUSE POPULATIONS IN NORTH AMERICA

Table C. General description and justification for delineation of greater sage-grouse breeding populations in North America (modified from Connelly et al. 2004).

Population name	Separation from adjacent population	Brief description of population and justification for its delineation
Baker OR	~30 km	Small population in Baker County OR. It appears separated by cropland from the nearest population, E-Central OR.
Bannack MT	~30–50 km and Continental Divide	Small population E of Lemhi Pass near Bannack MT. It appears separated from 4 adjacent populations by distance, narrow corridors, and the continental divide.
Belt Mountains MT	~70 km along narrow corridor	Small population or populations near Belt Mountains MT. In addition to being separated from the adjacent Central MT population, it also appears characterized by internal fragmentation.
Central OR	~30 km	Population in central OR is separated by distance and topography from Lake Area OR/NE CA/NW NV and E-Central OR populations. Fragmentation within population is substantial.
E Tavaputs Plateau UT	~50 km	Small population on E Tavaputs Plateau UT. It appears separated from adjacent populations by > 50 km.
Eagle/S Routt CO	~20-30 km and mountains	Small population along Colorado River in Eagle and S Routt counties CO. It appears isolated from 3 adjacent populations by both distance and topography.
E-Central ID	~30-50 km	Population E of Snake River in E-central ID. Population appears isolated by distance, topography, and habitat.
Great Basin Core	~20-60 km and topography	Large population in NV, SE OR, NE CA, SW ID, and NW UT. Natural fragmentation within population is common. Seven subpopulations have been delineated.
Gunnison Range UT	~200 km	Small translocated population of greater sage-grouse in SE UT within population of Gunnison sage-grouse. It is also isolated from nearest Gunnison sage-grouse populations by > 70 km.
Jackson Hole WY	~50 km	Small isolated population in Jackson Hole WY area. Population also appears internally fragmented.
Klamath OR/CA	~50 km	Small population on E side of Klamath Basin OR and CA. Population also appears internally fragmented.
Laramie WY	~30 km and mountains	Small population SW of Laramie WY. Appears isolated by both distance and topography from adjacent populations.
Middle Park CO	~20-30 km and mountains	Population in Middle Park CO appears isolated from North Park CO and Garfield CO populations
Moses Coulee WA	~50 km and Columbia River	Population along Moses Coulee in N-central WA is isolated by distance and topography from Yakima WA population. Peripheral parts of population are extirpated.

MT/ND/NW SD	~30-40 km	Population centered in SW ND and NW SD is largely isolated by distance and habitat from E-Interior MT/NE Tip WY population. Internal fragmentation is also apparent.
N Mono Lake CA	~20-40 km and mountains	Population on N side of Mono Lake area in CA and NV is relatively isolated from adjacent populations by both distance and topography. There is some natural internal fragmentation also.
NE-Interior UT	~30-50 km	Population in NW-interior portion of Utah appears isolated by both distance and topography from adjacent populations. Natural fragmentation within population is also a factor.
Northern MT	~20 km and Missouri River	Large population N of Missouri River in N-central MT, SE AB, and SW SK. Divided into 3 subpopulations.
NW-Interior NV	~20-30 km	Topographically dispersed population in interior NV. It appears largely isolated from 5 adjacent populations.
Piceance CO	~30-40 km	Small population in the Piceance Basin CO. Adjacent populations appear isolated by both distance and topography.
Pine Nut NV	~50-60 km and valleys	Small population in Pine Nut Mountains NV. Appears relatively isolated from adjacent populations by both distance and topography.
Red Rock MT	~20-40 km and mountains	Small, naturally fragmented population in SW Montana on N side of Monida Pass. Population appears isolated by distance and topography from adjacent populations.
S Mono Lake CA	~20-50 km and mountains	Small population on S side of Mono Lake area in CA appears relatively isolated from adjacent populations by both distance and topography. There is some natural internal fragmentation also.
S White River UT	~40-50 km	Small population S of White River UT. It is separated from adjacent populations by > 40 km.
Sanpete/Emery UT	~50-60 km	Small population in central UT that is isolated by both distance and topography.
Sawtooth ID	~70-80 km	Small isolated population near Stanley, ID in Sawtooth Mountains.
S-Central UT	~50-70 km and mountains	Clearly isolated population in S-central UT. Population appears to have a high degree of natural fragmentation within it.
Snake/Salmon/Beaverhead	~20-40 km	Large population along upper Snake, Salmon, and Beaverhead watersheds. Six subpopulations appear loosely connected through mountain valleys and passes.
Summit/Morgan UT	~20-4- km and mountains	Small population in NE UT appears separated from SW WY/NW CO/NE UT/SE ID by both distance and topography
Tooele/Juab UT	~40 km	Small isolated population in central UT. Population also appears naturally fragmented
Twin Bridges MT	~60 km	Small isolated population in SW MT.
Warm Springs Valley NV	~30-60 km and valleys	Small, fragmented, and isolated population along the W edge of NV.
Weiser ID	~20 km	Small and mostly isolated population in Weiser area of ID.

White River CO	~30-40 km and mountains	Small isolated population along White River CO.
Wisdom MT	~4-60 km	Small isolated population in SW MT.
Wyoming Basin	~20-30 km and topography	Massive population centered in WY. Seven subpopulations have been delineated.
Yakima WA	~50 km and Columbia River	Population near Yakima in S-central WA is isolated by distance and topography from Moses Coulee WA population. Peripheral parts of population are extirpated.
Yellowstone Watershed	~20-30 km	Large population in central and SE MT. Mostly separated from adjacent populations by distance and topography.

APPENDIX D: RANGE-WIDE POPULATION TRENDS

Monitoring Effort

Data from three time periods were analyzed. The time periods analyzed by population (if there were sufficient data) were 1965-2007, 1965-1985, and 1986-2007. Thirty-eight populations were identified for the analysis (Appendix C), although only 21 populations had sufficient quantities of data to construct trends for the time period of 1965-2007 (Table D.1). For the 1965-1985 time period, 21 populations had sufficient data for the trend analysis (Table D.2) and in the last time period (1986-2007), 29 populations had sufficient data for the trend analysis (Table D.3). Note that the best models are reported in these tables and the ΔAICs are those of the next best approximating model.

Lek-count Trends

Survey effort, average and median number of males/lek, and the best approximating models for the long-term trends for 1965-2007, 1965-1985, and 1986-2007 were estimated for each population with sufficient data (Tables D.1-D.4; Figs. D.1-D.87, arranged alphabetically by population name). Trend data in these analyses indicate that male counts vary by population. Of the 21 male-count trends analyzed for the time period of 1965-2007, 48% (n = 10/21) demonstrated decreasing trends, 52% (n = 11/21) demonstrated unknown trends (the confidence interval bands were overlapping therefore the trend could be decreasing, increasing or unchanged) (Table D.1). For the time period of 1965-1985, 43% (n = 9/21) demonstrated decreasing male-count trends, 52% (n = 11/21) have unknown trends, and 5% (n = 1/21) shows an increasing trend (Table D.2). For the 29 populations analyzed for the time period of 1986-2007, there appears to be a higher degree of uncertainty in the trends of the male-count (Table

D.3). Ten percent (n = 3/29) demonstrated decreasing trend, and 90% (n = 26/29) had unknown

trends. Although lek-count effort generally increased over time, this varied by population (Table

D.4).

Table D.1. Male-count trend by population as represented by the best fit fixed effect model and the resulting statistics of the intercept, constant (C) linear (L), and quadratic (Q) models, the 95% lower (LCI) and upper (UCI) 95% confidence intervals (CI) and standard deviations (SD) for the timeframe 1965-2007.

Population	ΔAIC	Model	Start Year	Leks	Counts	β_0	SD	95% CI LCI	UCI	β_1	SD	95% CI LCI	UCI	β_2	SD	95% CI LCI	UCI
Baker OR	0.76	L	1989	15	168	3.055	3.119	0.996	5.114	-0.020	0.091	-0.078	0.037				
Bannack MT	56.8	L	1965	13	151	3.191	0.385	2.435	3.947	-0.014	0.046	-0.043	0.015				
Belt Mountains MT	27.9	Q	1973	7	92	5.483	0.891	4.450	6.517	-0.198	0.135	-0.329	-0.066	0.003	0.003	0.001	0.006
Central OR	143.3	Q	1965	115	1590	1.725	4.305	0.407	3.043	0.045	0.301	-0.040	0.130	-0.001	0.005	-0.003	0.000
E Tavaputs Plateau UT	4.07	L	1976	2	24	2.554	0.000	1.599	3.510	-0.067	0.000	-0.101	-0.033				
Eagle/S Routt CO	44.9	L	1986	21	261	2.368	2.671	1.021	3.714	-0.036	0.073	-0.073	0.001				
E-Central ID	6.34	Q	1965	7	118	1.729	0.978	0.663	2.795	0.099	0.101	-0.016	0.214	-0.005	0.003	-0.008	-0.001
Great Basin Core	558.7	Q	1965	673	7924	3.612	2.315	3.268	3.956	-0.077	0.199	-0.102	-0.052	0.001	0.004	0.001	0.001
Gunnison Range UT[1]																	
Jackson Hole WY	21.7	L	1989	11	114	4.782	0.966	3.641	5.923	-0.073	0.053	-0.116	-0.031				
Klamath OR/CA	2.62	L	1977	4	25	2.695	0.816	1.506	3.884	-0.041	0.010	-0.068	-0.014				
Laramie WY	3.86	L	1965	4	37	3.695	0.000	3.365	4.024	-0.090	0.000	-0.101	-0.078				
Middle Park CO	4.21	L	1986	32	358	1.986	2.069	1.077	2.895	0.007	0.069	-0.024	0.038				
Moses Coulee WA	160.8	Q	1965	25	632	4.265	1.028	3.740	4.789	-0.164	0.164	-0.236	-0.092	0.002	0.003	0.001	0.004
MT/ND/NW SD	442.7	L	1965	65	1145	2.573	1.280	2.170	2.976	-0.024	0.048	-0.038	-0.010				
N Mono Lake CA	6.03	L	1965	19	486	2.964	1.374	2.097	3.123	-0.060	0.096	-0.034	-0.004				
NE Interior UT	35.0	Q	1969	35	557	3.332	1.565	2.560	4.104	-0.103	0.160	-0.176	-0.031	0.001	0.004	0.000	0.003
Northern MT	85.2	L	1965	125	824	2.721	0.841	2.396	3.046	0.009	0.040	-0.002	0.019				
NW Interior NV[1]																	
Piceance CO	1.83	L	1986	32	244	-0.300	3.454	-2.120	1.520	0.042	0.092	-0.005	0.089				
Pine Nut NV[2]																	
Red Rock MT	12.1	Q	1965	10	116	11.748	8.028	5.617	17.879	-0.606	0.654	-1.101	-0.111	0.009	0.011	0.001	0.018
S Mono Lake CA	3.24	L	1965	13	364	2.715	1.504	1.782	3.647	-0.015	0.060	-0.051	0.021				
S White River UT	34.8	L	1983	5	57	5.219		4.156	6.281	-0.095	0.042	-0.140	-0.049				
Sanpete/Emery UT[1]																	
Sawtooth ID[2]																	
S-Central UT	95.8	Q	1967	40	834	3.483	1.194	2.937	4.028	-0.124	0.120	-0.176	-0.073	0.002	0.002	0.001	0.003
Snake/Salmon/Beaverhead	384.5	Q	1965	407	6173	3.645	1.871	3.332	3.959	-0.109	0.164	-0.134	-0.084	0.002	0.003	0.001	0.002
Summit/Morgan UT	25.6	Q	1965	15	234	3.616	0.773	2.953	4.279	-0.131	0.111	-0.210	-0.053	0.002	0.003	0.000	0.004
Tooele/Juab UT	14.8	Q	1965	10	165	4.080	0.647	3.250	4.910	-0.183	0.157	-0.316	-0.050	0.004	0.004	0.001	0.006
Twin Bridges MT[1]																	
Warm Springs Valley NV	3.99	C	1992	2	12	3.450	0.581	2.493	4.408								
Weiser ID	16.2	L	1967	19	234	3.107	0.266	2.777	3.437	-0.021	0.036	-0.040	-0.001				
White River CO[1]																	
Wisdom MT	5.18	L	2000	4	32	6.534	4.477	1.337	11.730	-0.092	0.127	-0.236	0.053				
Wyoming Basin	543.8	Q	1965	1425	12340	3.975	5.262	3.456	4.494	-0.122	0.357	-0.155	-0.089	0.002	0.006	0.002	0.003
Yakima WA	40.4	L	1970	11	175	4.216	1.175	3.278	5.154	-0.060	0.053	-0.096	-0.023				
Yellowstone Watershed	103.6	Q	1965	249	2907	3.865	2.155	3.428	4.302	-0.087	0.184	-0.123	-0.051	0.001	0.004	0.000	0.002

[1] Insufficient or no data for analysis. * Only one model converged, therefore no Delta AIC exists.

Table D.2. Male-count trend by population as represented by the best fit fixed effect model and the resulting statistics of the intercept, constant (C) linear (L), and quadratic (Q) models the 95% lower (LCI) and upper (UCI) confidence intervals (95% CI) and standard deviations (SD) for the timeframe 1965 - 1985.

Population	ΔAIC	Model	Start Year	Leks	Counts	β_0	SD	95% CI LCI	95% CI UCI	β_1	SD	95% CI LCI	95% CI UCI	β_2	SD	95% CI LCI	95% CI UCI
Baker OR[1]			1965														
Bannack MT	39.0	L	1965	4	64	2.798	1.157	1.576	4.021	0.030	0.081	-0.055	0.114				
Belt Mountains MT	116.9	L	1965	2	26	4.931	0.271	4.152	5.710	-0.094	0.012	-0.141	-0.048				
Central OR	23.3	Q	1965	34	297	2.805	1.297	2.106	3.505	-0.124	0.245	-0.252	0.003	0.004	0.010	-0.002	0.009
E Tavaputs Plateau UT[1]			1965														
Eagle/S Routt CO			1965														
E-Central ID	4.54	L	1965	7	62	2.893	0.937	1.823	3.962	-0.053	0.076	-0.133	0.027				
Great Basin Core	56.4	Q	1965	240	1606	2.308	1.491	1.900	2.716	0.108	0.241	0.044	0.172	-0.006	0.009	-0.008	-0.003
Gunnison Range UT[1]			1965														
Jackson Hole WY[1]			1965														
Klamath OR/CA[1]			1965														
Laramie WY	5.48	L	1965	4	18	4.161	0.000	3.275	5.047	-0.183	0.000	-0.355	-0.010				
Middle Park CO[1]			1965														
Moses Coulee WA	3.76	L	1965	20	222	4.066	0.550	3.703	4.430	-0.117	0.096	-0.165	-0.070				
MT/ND/NW SD	93.4	L	1965	35	427	2.553	1.030	2.142	2.964	-0.054	0.073	-0.086	-0.023				
N Mono Lake CA	2.08	L	1965	18	200	2.868	1.093	2.182	3.553	-0.045	0.060	-0.087	-0.004				
NE Interior UT	4.27	L	1965	24	212	3.220	1.176	2.560	3.879	-0.082	0.060	-0.124	-0.041				
Northern MT	5.10	C	1965	12	82	2.960	0.030	2.770	3.149								
NW Interior NV[1]			1965														
Piceance CO[1]			1965														
Pine Nut NV[1]			1965														
Red Rock MT	1.81	L	1965	2	22	4.608	0.000	4.317	4.900	-0.032	0.000	-0.054	-0.009				
S Mono Lake CA	*	C	1965	10	145	2.260	0.799	1.721	2.798								
S White River UT[1]			1965														
Sanpete/Emery UT[1]			1965														
Sawtooth ID[1]			1965														
S-Central UT	49.8	L	1965	30	348	3.210	0.998	2.724	3.697	-0.077	0.069	-0.112	-0.042				
Snake/ Salmon/Beaverhead	126.2	Q	1965	232	1972	3.005	1.318	2.696	3.314	-0.024	0.290	-0.084	0.035	-0.002	0.014	-0.004	0.001
Summit/Morgan UT	13.8	Q	1965	11	139	2.198	1.186	1.138	3.259	0.180	0.231	-0.018	0.378	-0.011	0.008	-0.019	-0.004
Tooele/Juab UT	2.08	L	1965	6	73	4.173	0.386	3.576	4.770	-0.161	0.095	-0.247	-0.074				
Twin Bridges MT[1]			1965														
Warm Springs Valley NV[1]			1965														
Weiser ID	36.4	L	1965	7	63	4.176	3.363	1.408	6.944	-0.096	0.228	-0.284	0.092				
White River CO[1]			1965														
Wisdom MT[1]			1965														
Wyoming Basin	45.6	Q	1965	340	1241	3.513	1.255	3.167	3.859	-0.053	0.243	-0.114	0.009	0.001	0.010	-0.002	0.003
Yakima WA	14.8	L	1965	5	31	1.470	0.135	0.821	2.120	0.104	0.041	0.046	0.163				
Yellowstone Watershed	34.9	Q	1965	143	957	2.072	1.927	1.393	2.752	0.120	0.291	0.021	0.219	-0.005	0.010	-0.008	-0.001

[1] Insufficient or no data for analysis * Only one model converged, therefore no Delta AIC exists.

Table D.3. Male -count trend by population as represented by the best fit fixed effect model and the resulting statistics of the intercept, constant (C) linear (L), and quadratic (Q) models the 95% lower (LCI) and upper (UCI) confidence intervals (95% CI) and standard deviations (SD) for the timeframe 1986 - 2007.

Population	ΔAIC	Model	Start Year	Leks	Counts	β_0	SD	95% CI LCI	95% CI UCI	β_1	SD	95% CI LCI	95% CI UCI	β_2	SD	95% CI LCI	95% CI UCI
Baker OR	20.3	L	1989	15	168	2.631	1.356	1.711	3.551	-0.020	0.091	-0.078	0.037				
Bannack MT	20.8	Q	1986	13	87	3.545	0.000	3.300	3.790	-0.185	0.088	-0.260	-0.110	0.007	0.002	0.004	0.010
Belt Mountains MT	7.28	L	1986	7	66	2.012	1.733	0.436	3.587	0.047	0.079	-0.028	0.123				
Central OR	61.1	Q	1986	113	1293	2.253	1.152	1.897	2.610	-0.014	0.198	-0.070	0.043	-0.001	0.008	-0.003	0.001
E Tavaputs Plateau UT[1]			1986														
Eagle/S Routt CO	6.88	Q	1986	21	261	1.774	1.077	1.205	2.344	-0.078	0.078	-0.143	0.043	0.002	0.004	-0.001	0.005
E-Central ID	4.58	L	1986	6	56	2.151	1.394	0.939	3.365	-0.036	0.144	-0.165	0.094				
Great Basin Core	386.0	Q	1986	666	6318	2.815	1.707	2.595	3.036	-0.095	0.262	-0.127	-0.062	0.003	0.010	0.002	0.004
Gunnison Range UT[1]			1986														
Jackson Hole WY	21.7	L	1986	11	114	3.239	0.137	2.837	3.642	-0.073	0.053	-0.116	-0.031				
Klamath OR/CA	2.93	C	1986	4	21	1.293	1.060	0.159	2.427								
Laramie WY	4.47	C	1986	4	19	0.181	0.087	-0.108	0.471								
Middle Park CO	9.66	Q	1986	32	358	1.883	0.965	1.452	2.313	0.066	0.153	-0.013	0.145	-0.002	0.006	-0.006	0.001
Moses Coulee WA	43.6	Q	1986	25	410	1.768	1.456	1.118	2.418	-0.054	0.192	-0.143	0.035	0.002	0.007	-0.001	0.005
MT/ND/NW SD	108.9	Q	1986	63	718	2.404	1.517	1.923	2.885	-0.082	0.220	-0.154	-0.009	0.002	0.009	-0.001	0.005
N Mono Lake CA	9.82	Q	1986	19	286	2.515	1.601	1.709	3.321	-0.113	0.172	-0.218	-0.009	0.005	0.005	0.001	0.008
NE Interior UT	29.2	Q	1986	34	345	2.645	1.360	1.983	3.306	-0.210	0.172	-0.306	-0.113	0.008	0.008	0.004	0.012
Northern MT	*	C	1986	125	742	3.059	0.727	2.921	3.197								
NW Interior NV[1]			1986														
Piceance CO	5.08	Q	1986	32	244	1.630	1.398	0.626	2.634	-0.128	0.243	-0.281	0.024	0.006	0.010	0.000	0.012
Pine Nut NV[1]			1986														
Red Rock MT	*	C	1986	10	94	2.443	0.607	1.989	2.897								
S Mono Lake CA	9.48	Q	1986	13	219	3.492	0.674	2.975	4.009	-0.198	0.167	-0.317	-0.079	0.006	0.008	0.001	0.012
S White River UT	3.10	L	1986	5	53	3.340	0.276	2.772	3.908	-0.101	0.040	-0.149	-0.053				
Sanpete/Emery UT[1]			1986														
Sawtooth ID[1]			1986														
S-Central UT	38.8	Q	1986	36	386	2.384	1.450	1.788	2.981	-0.110	0.184	-0.196	-0.024	0.006	0.007	0.002	0.009
Snake/ Salmon/Beaverhead	648.9	Q	1986	384	4201	3.035	1.479	2.801	3.269	-0.232	0.287	-0.272	-0.192	0.009	0.011	0.007	0.010
Summit/Morgan UT	7.10	L	1986	14	95	1.058	0.966	0.428	1.688	0.017	0.066	-0.027	0.061				
Tooele/Juab UT	4.05	C	1986	10	92	2.093	0.828										
Twin Bridges MT[1]			1986														
Warm Springs Valley NV[1]			1986														
Weiser ID	5.79	L	1986	18	171	2.678	1.385	1.871	3.484	-0.006	0.092	-0.058	0.046				
White River CO[1]			1986														
Wisdom MT	5.25	L	1986	4	32	4.608	1.816	2.436	6.780	-0.092	0.127	-0.236	0.052				
Wyoming Basin	724.9	Q	1986	1408	11099	2.345	1.853	2.174	2.516	-0.044	0.281	-0.069	-0.020	0.003	0.011	0.002	0.003
Yakima WA	5.13	L	1986	11	144	3.185	1.085	2.434	3.936	-0.072	0.061	-0.116	-0.027				
Yellowstone Watershed	138.3	Q	1986	249	1950	2.628	1.356	2.358	2.897	-0.115	0.222	-0.158	-0.072	0.004	0.009	0.003	0.006

[1] Insufficient or no data for analysis. * Only one model converged, therefore no Delta AIC exists.

Table D.4. Male-count summary statistics by population of the number of leks counted, the average and median males per lek during 9 time intervals.

	Starting Year	YEAR INTERVALS								
		1965 - 69	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990 - 94	1995 - 99	2000 - 04	2004 - 07
Baker OR	1989									
Number of Leks						1.2	3.6	9.2	11.4	13.7
Average males/lek						18.2	10.9	13.1	14.5	14.3
Median males/lek						11.0	6.5	11.5	13.0	10.0
Bannack MT	1965									
Number of Leks		2.0	2.4	3.6	4.0	3.6	2.2	3.0	7.6	4.7
Average males/lek		18.0	29.7	38.6	30.2	22.8	18.9	13.1	18.6	25.0
Median males/lek		13.0	33.5	35.5	27.5	22.0	20.0	14.0	16.0	20.0
Belt Mountains MT	1973									
Number of Leks			0.8	2.0	2.0	1.4	2.0	2.6	4.8	3.0
Average males/lek			70.8	37.4	28.9	15.7	15.3	19.2	21.4	21.4
Median males/lek			72.5	36.5	27.5	16.0	16.5	20.0	22.0	18.0
Central OR	1965									
Number of Leks		15.6	12.2	10.4	18.6	26.4	38.8	57.0	83.8	92.0
Average males/lek		21.1	12.6	11.2	11.0	12.5	11.3	10.6	9.0	9.4
Median males/lek		14.0	9.0	7.0	7.0	9.0	9.0	8.0	6.0	4.0
E Tavaputs Plateau UT	1976									
Number of Leks				0.6	0.8	1.2	0.8		0.8	1.0
Average males/lek				16.0	1.8	2.0	2.3		0.0	0.0
Median males/lek				16.0	0.5	1.5	0.5		0.0	0.0
Eagle/S Routt CO	1986									
Number of Leks						9.6	9.8	11.2	13.2	14.0
Average males/lek						6.4	6.6	3.8	6.5	6.6
Median males/lek						1.5	0.0	0.0	0.0	3.0
E-Central ID	1965									
Number of Leks		1.8	3.2	2.8	3.8	3.4	2.6	3.8	2.2	
Average males/lek		15.3	19.1	14.9	15.1	13.1	13.1	5.2	6.5	
Median males/lek		10.0	17.5	12.5	11.0	11.0	9.0	4.0	0.0	
Great Basin Core NV	1965									
Number of Leks		28.6	71.2	80.0	116.4	124.4	166.2	275.2	432.2	484.3
Average males/lek		25.5	26.1	27.2	24.4	24.6	24.4	14.4	18.8	24.3
Median males/lek		15.0	17.0	20.0	17.0	17.0	17.0	10.0	12.0	16.0
Gunnison Range UT										
Number of Leks					0.6	1.0	1.0	1.0		
Average males/lek					6.0	10.4	7.4	0.8		
Median males/lek					6.0	11.0	6.0	0.0		
Jackson Hole WY	1989									
Number of Leks						1.4	5.8	7.6	3.6	7.3
Average males/lek						23.3	26.3	10.4	20.2	16.9
Median males/lek						8.0	21.0	6.0	18.5	16.5

Table D.4. Continued (male-count summary statistics by population of the number of leks counted, the average and median males per lek during 9 time intervals).

	Starting Year	1965 - 69	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990 - 94	1995 - 99	2000 - 04	2004 - 07
Klamath OR/CA	1977									
Number of Leks				0.4	0.4		1.4	1.2	1.0	1.0
Average males/lek				2.5	2.0		0.7	7.3	3.0	7.7
Median males/lek				2.5	2.0		0.0	5.5	0.0	6.0
Laramie WY	1965									
Number of Leks		2.2	1.4				0.4	0.4	1.6	2.3
Average males/lek		37.5	21.6				1.5	0.0	1.0	0.0
Median males/lek		37.0	18.0				1.5	0.0	0.0	0.0
Middle Park CO	1986									
Number of Leks						13.4	17.4	13.8	16.8	17.0
Average males/lek						10.5	10.7	12.4	17.0	15.3
Median males/lek						8.0	9.0	11.0	15.5	12.0
Moses Coulee WA	1965									
Number of Leks		2.6	12.2	12.4	14.4	15.8	16.0	19.2	21.0	21.3
Average males/lek		33.2	26.2	13.7	22.1	13.7	12.3	12.3	10.3	10.5
Median males/lek		31.0	21.0	13.0	22.0	5.0	4.0	6.0	2.0	6.5
MT/ND/NW SD	1965									
Number of Leks		19.0	18.6	18.2	24.6	23.2	29.8	29.0	37.8	48.0
Average males/lek		13.4	15.4	9.9	13.1	10.1	11.8	7.2	9.8	14.7
Median males/lek		11.0	16.0	9.0	9.0	5.5	9.0	5.0	7.0	12.0
N Mono Lake CA	1965									
Number of Leks		4.8	9.6	10.6	12.4	14.6	13.4	11.0	12.8	13.3
Average males/lek		27.6	25.3	24.9	19.2	18.0	21.4	10.5	18.9	19.4
Median males/lek		18.5	17.5	16.0	13.5	13.0	21.0	5.0	12.5	13.5
NE Interior UT	1969									
Number of Leks		1.0	9.8	16.4	12.8	12.2	15.2	11.2	18.4	24.0
Average males/lek		8.6	18.7	23.9	9.3	15.5	9.6	8.6	10.8	14.2
Median males/lek		4.0	14.0	13.0	5.5	9.0	7.0	3.0	5.0	4.0
Northern MT	1965									
Number of Leks		2.2	2.2	4.2	6.2	8.6	12.0	18.6	77.2	56.0
Average males/lek		25.6	27.6	17.9	26.5	22.2	21.0	21.6	27.8	29.6
Median males/lek		24.0	28.0	22.0	25.0	19.0	19.0	20.0	24.0	27.0
NW Interior NV										
Number of Leks										
Average males/lek										
Median males/lek										
Piceance CO	1986									
Number of Leks						5.4	4.8	7.0	14.2	29.0
Average males/lek						5.3	2.9	2.9	4.2	6.7
Median males/lek						0.0	0.0	0.0	0.0	5.0

Table D.4. Continued (male-count summary statistics by population of the number of leks counted, the average and median males per lek during 9 time intervals).

	Starting Year	YEAR INTERVALS								
		1965 - 69	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990 - 94	1995 - 99	2000 - 04	2004 - 07
Pine Nut NV										
Number of Leks										
Average males/lek										
Median males/lek										
Red Rock MT	1965									
Number of Leks		1.0	1.0	1.0	1.0	4.0	3.6	4.4	6.2	1.7
Average males/lek		103.6	72.8	56.8	70.6	28.8	19.9	16.2	20.4	25.2
Median males/lek		100.0	70.0	69.0	62.0	28.0	16.0	15.5	14.0	19.0
S Mono Lake CA	1965									
Number of Leks		5.4	7.2	7.2	7.4	9.0	10.8	10.4	9.8	9.3
Average males/lek		12.5	17.6	13.9	16.5	37.2	19.7	19.7	21.9	11.9
Median males/lek		6.0	13.0	12.0	12.0	22.0	9.0	14.0	10.0	7.5
S White River UT	1983									
Number of Leks					0.4	1.6	1.6	1.8	3.0	5.0
Average males/lek					19.0	27.4	15.6	16.4	7.9	5.8
Median males/lek					19.0	27.0	15.5	12.0	5.0	5.0
Sanpete/Emery UT										
Number of Leks							0.8	1.0	1.0	1.0
Average males/lek							13.3	15.6	8.0	18.0
Median males/lek							15.5	15.0	8.0	12.0
Sawtooth ID										
Number of Leks					1.0	0.4	0.4	0.2	0.2	
Average males/lek					10.6	2.0	2.5	0.0	0.0	
Median males/lek					11.0	2.0	2.5	0.0	0.0	
S-Central UT	1967									
Number of Leks		8.4	20.4	22.6	14.4	18.8	14.8	22.0	27.2	30.3
Average males/lek		33.5	27.6	18.1	18.2	17.3	20.1	21.2	25.6	34.5
Median males/lek		26.0	21.0	13.0	14.0	11.5	11.0	10.5	14.0	22.0
Snake/Salmon/Beaverhead	1965									
Number of Leks		74.4	89.0	103.0	113.4	105.8	149.2	198.0	256.8	241.7
Average males/lek		36.0	30.4	27.6	15.6	23.2	13.2	11.1	15.7	20.9
Median males/lek		28.5	23.0	19.0	10.0	16.0	5.5	3.0	8.0	13.0
Summit/Morgan UT	1965									
Number of Leks		4.6	7.6	8.8	6.2	5.2	2.4	1.0	6.8	7.0
Average males/lek		19.5	28.1	18.6	13.6	5.6	15.2	44.0	12.8	15.7
Median males/lek		17.0	28.0	10.0	8.0	0.0	7.5	34.0	1.0	12.0
Tooele/Juab UT	1965									
Number of Leks		1.0	4.0	5.4	3.4	5.2	3.0	2.4	4.6	6.7
Average males/lek		28.0	22.3	14.6	7.5	13.3	13.7	11.9	22.6	21.4
Median males/lek		26.0	20.0	11.0	3.0	13.0	14.0	6.5	12.0	16.0

Table D.4. Continued (male-count summary statistics by population of the number of leks counted, the average and median males per lek during 9 time intervals).

	Starting Year	YEAR INTERVALS								
		1965 - 69	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990 - 94	1995 - 99	2000 - 04	2004 - 07
Twin Bridges, MT										
Number of Leks								0.4	0.4	
Average males/lek								0.0	6.5	
Median males/lek								0.0	6.5	
Warm Springs Valley NV	1992									
Number of Leks							0.2		1.0	2.0
Average males/lek							75.0		32.0	46.8
Median males/lek							75.0		24.0	42.0
Weiser ID	1967									
Number of Leks		0.6	3.4	3.8	4.0	3.8	3.0	5.2	14.6	14.0
Average males/lek		23.3	19.8	28.1	11.7	5.9	27.8	20.6	19.3	19.5
Median males/lek		24.0	18.0	27.0	8.5	6.0	34.0	18.0	18.0	16.5
White River CO										
Number of Leks										
Average males/lek										
Median males/lek										
Wisdom MT	2000									
Number of Leks									4.8	2.7
Average males/lek									23.7	26.8
Median males/lek									19.0	28.5
Wyoming Basin	1965									
Number of Leks		39.2	48.6	50.8	84.6	222.6	239.6	414.4	767.8	1000.7
Average males/lek		44.1	32.3	29.8	29.6	21.2	17.8	17.3	21.8	33.7
Median males/lek		33.0	26.0	18.0	20.0	12.0	10.0	10.0	14.0	21.0
Yakima WA	1970									
Number of Leks			1.0	2.2	2.4	3.6	5.0	6.8	9.0	8.3
Average males/lek			12.2	19.5	57.9	30.3	24.0	16.6	14.5	11.5
Median males/lek			12.0	15.0	48.0	27.0	22.0	15.0	15.0	9.0
Yellowstone Watershed	1965									
Number of Leks		7.4	38.4	57.8	72.8	88.4	71.6	77.6	102.4	108.3
Average males/lek		21.5	24.6	24.5	28.7	18.1	15.3	13.0	20.1	25.4
Median males/lek		14.0	20.0	20.0	25.0	13.0	10.0	8.0	16.0	21.0
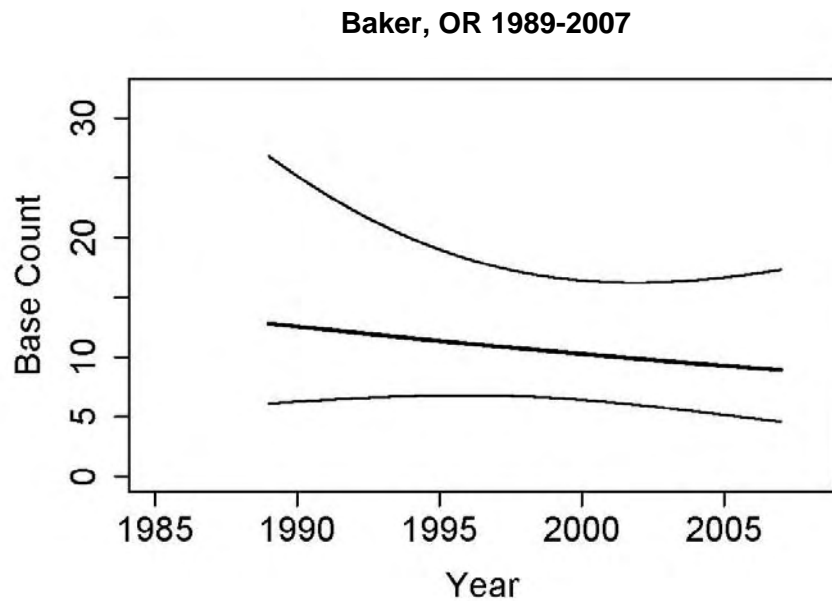
Figure D.1. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model.
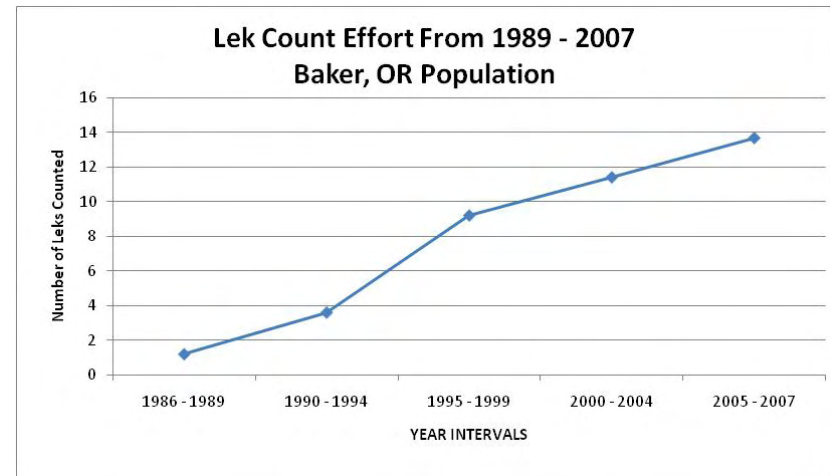
Figure D.2. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1989-2007 in Baker, OR population.
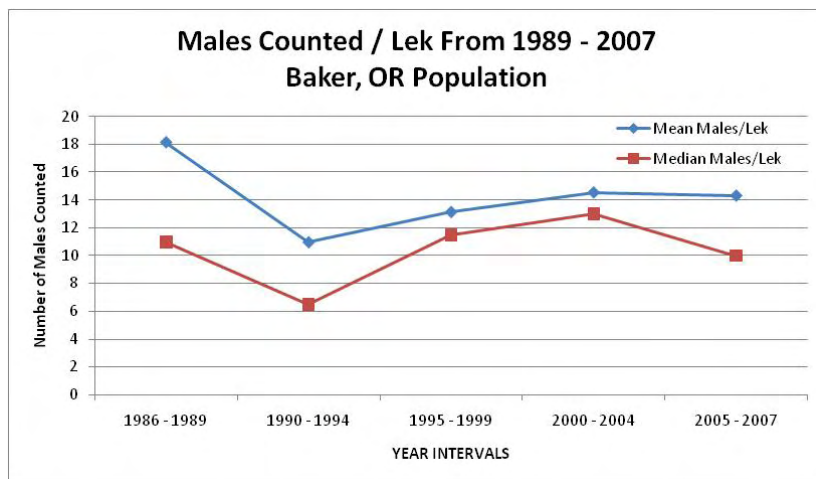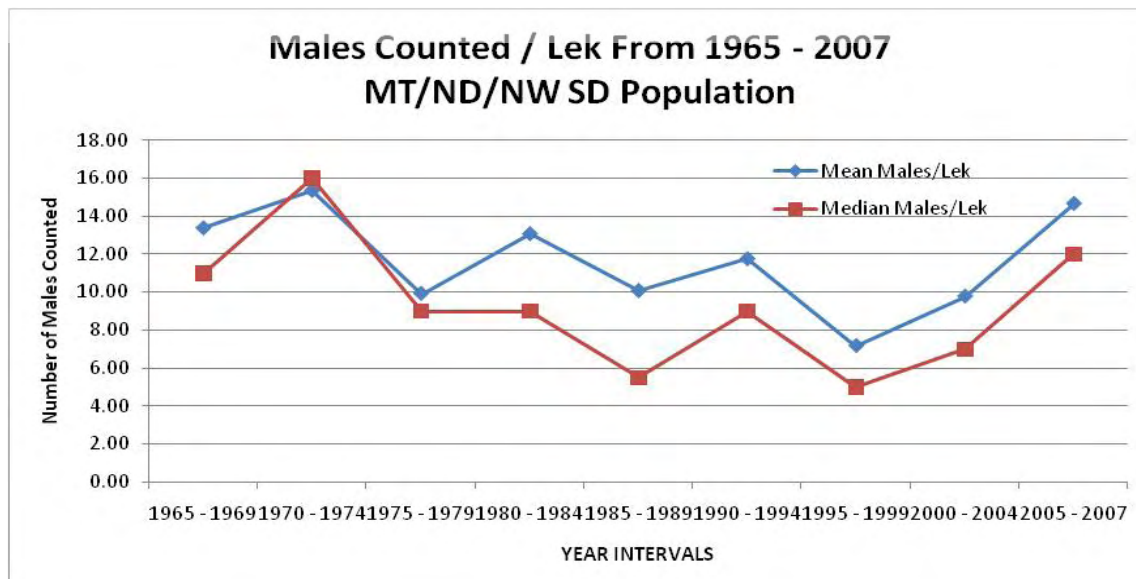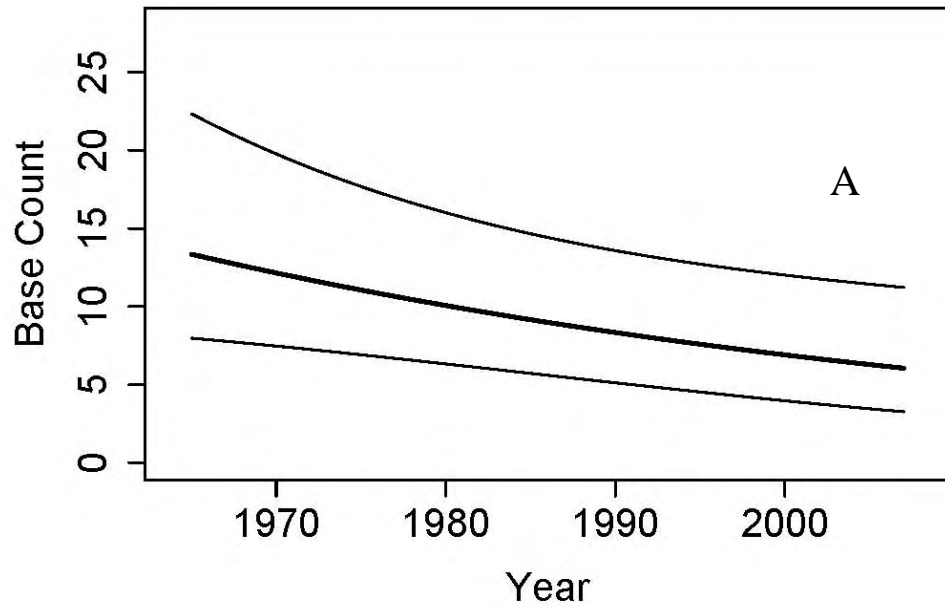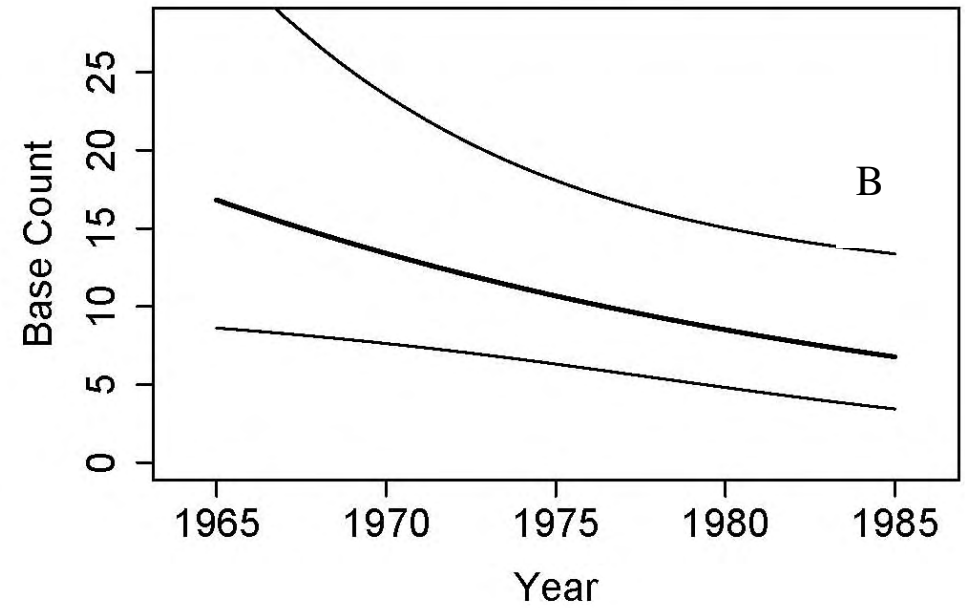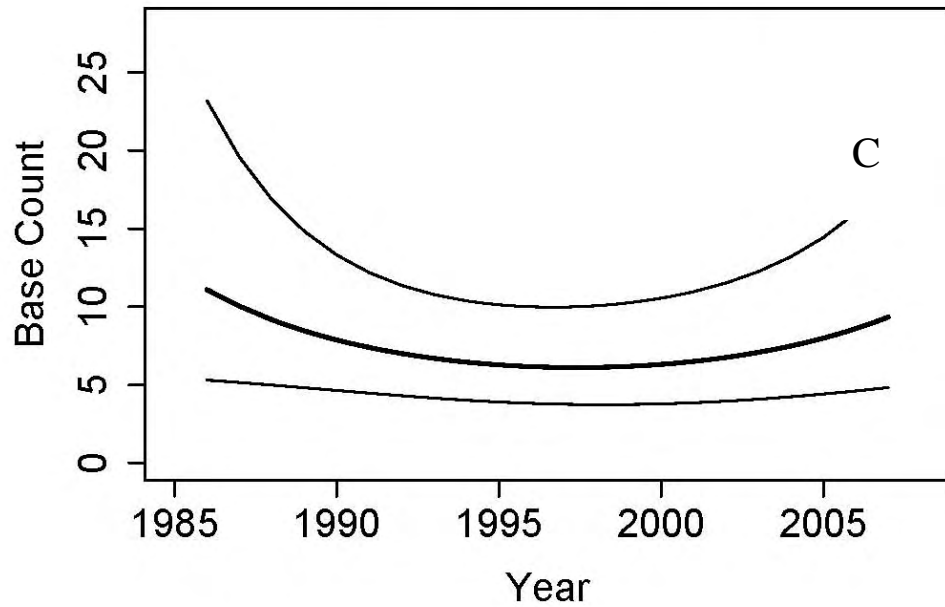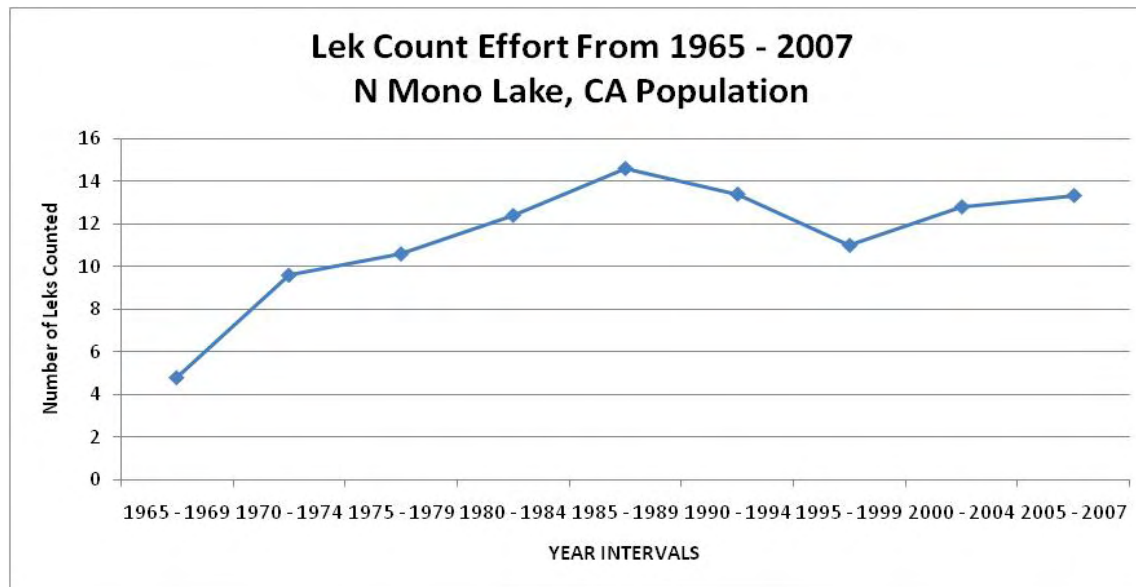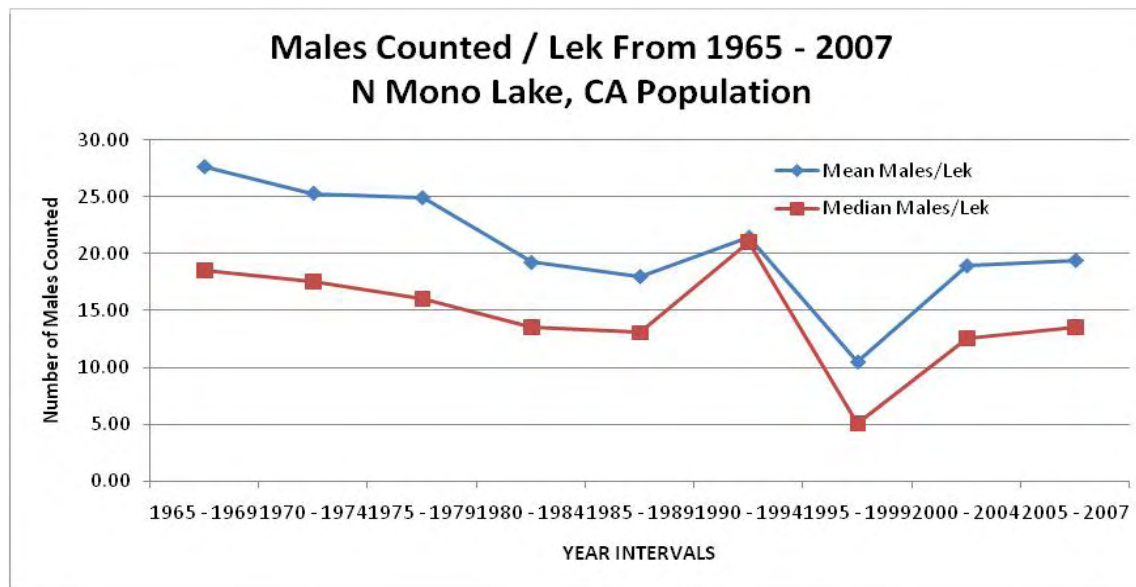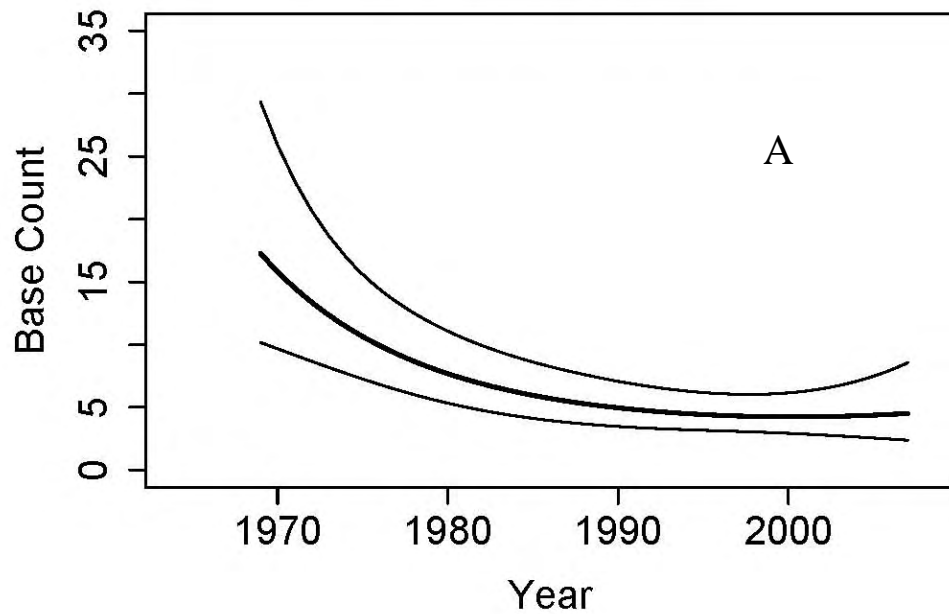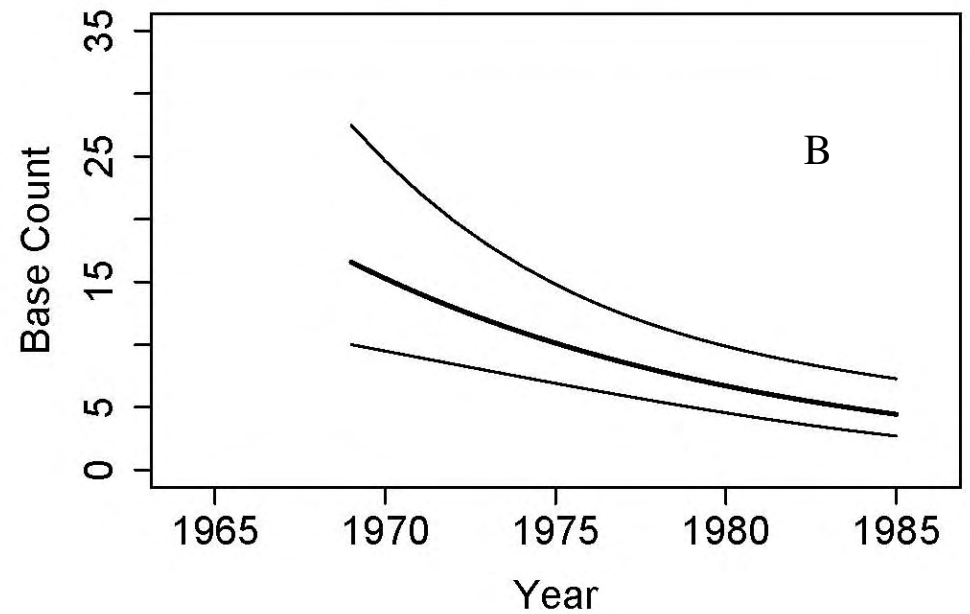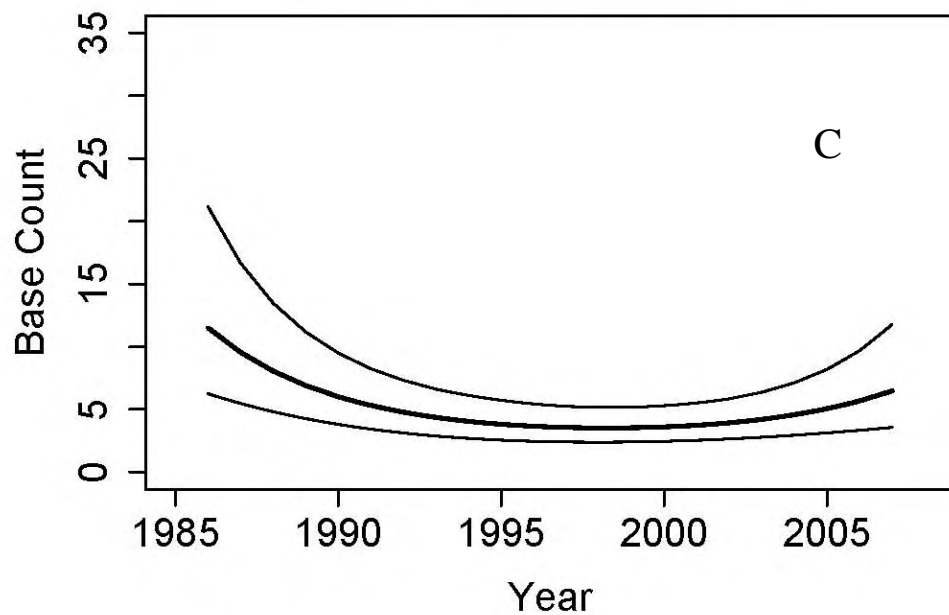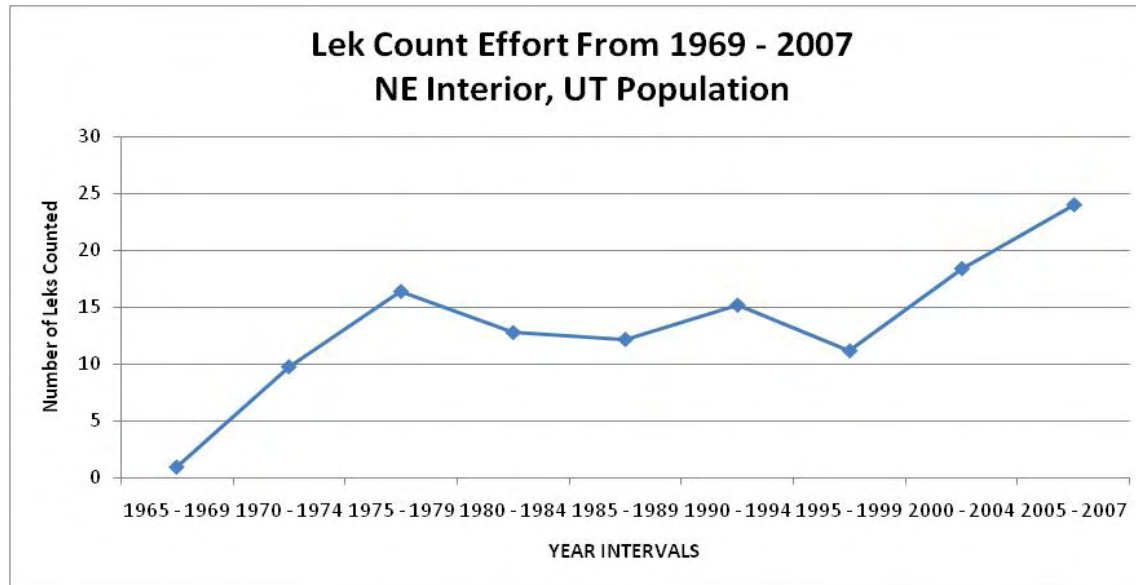

Figure D.3. The mean and median number of males counted on leks during time intervals from 1989 - 2007 in Baker, OR population.
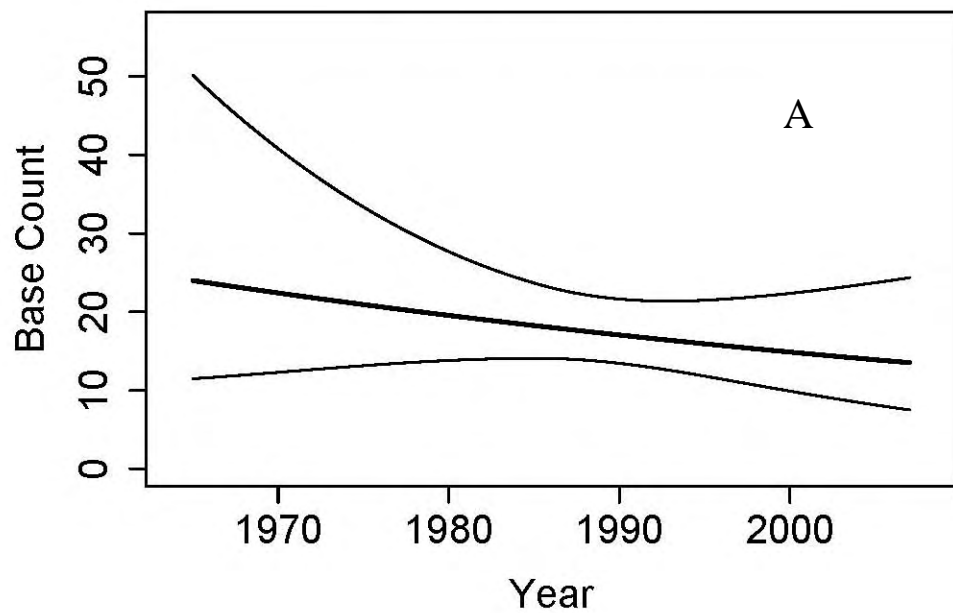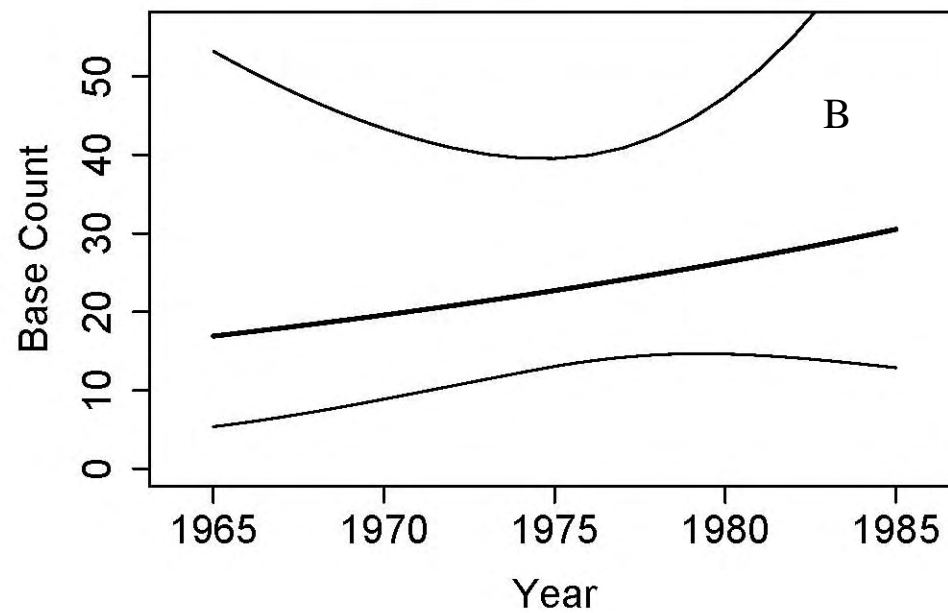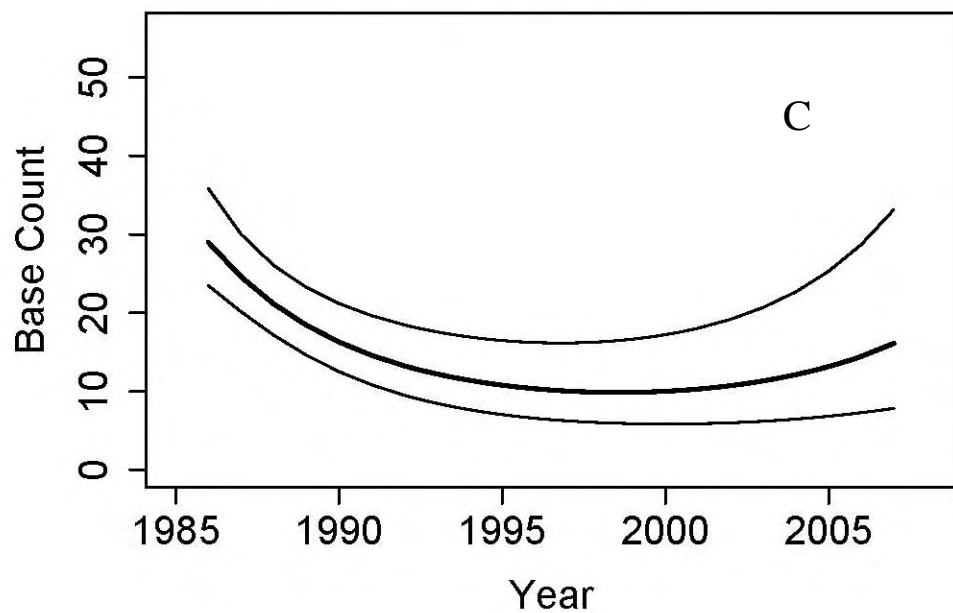
Figure D.4. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1965 – 2007 (A) and 1965 – 1985 (B) but a quadratic model for 1986 – 2007 (C).
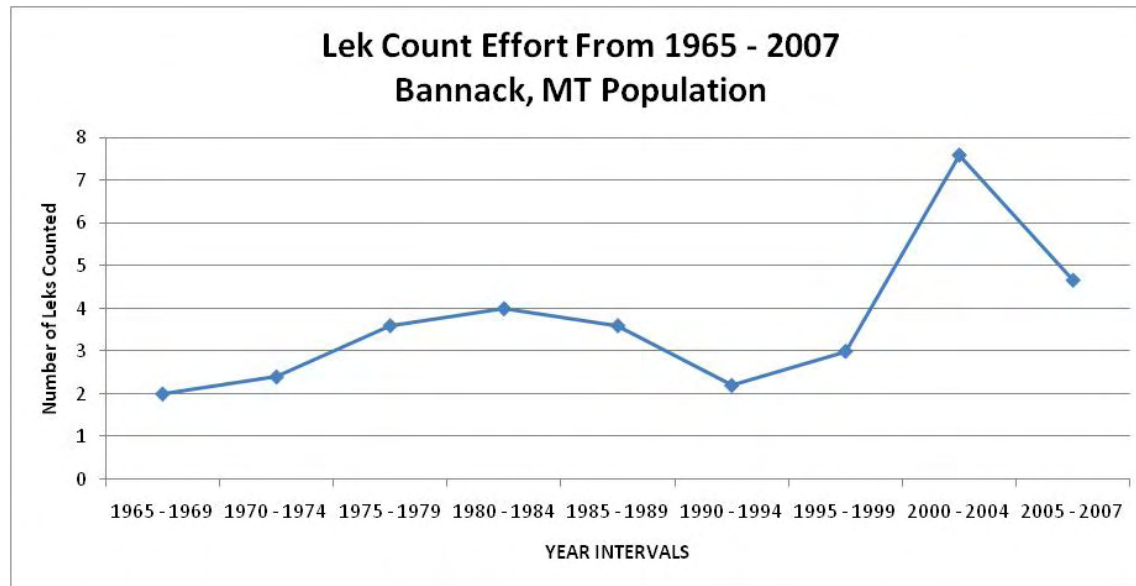
Figure D.5. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in Bannack, MT population.
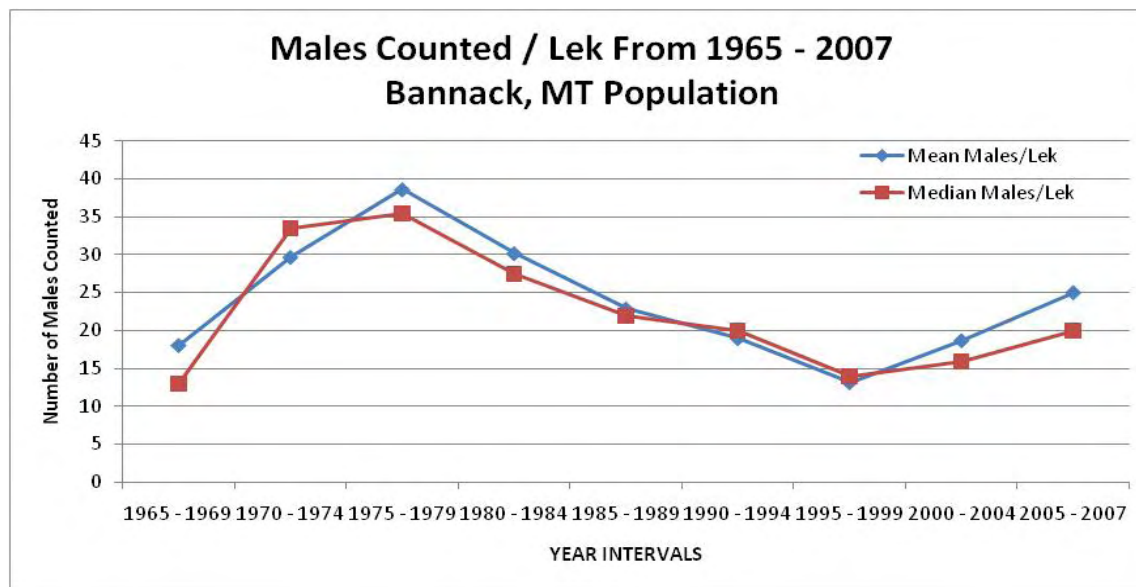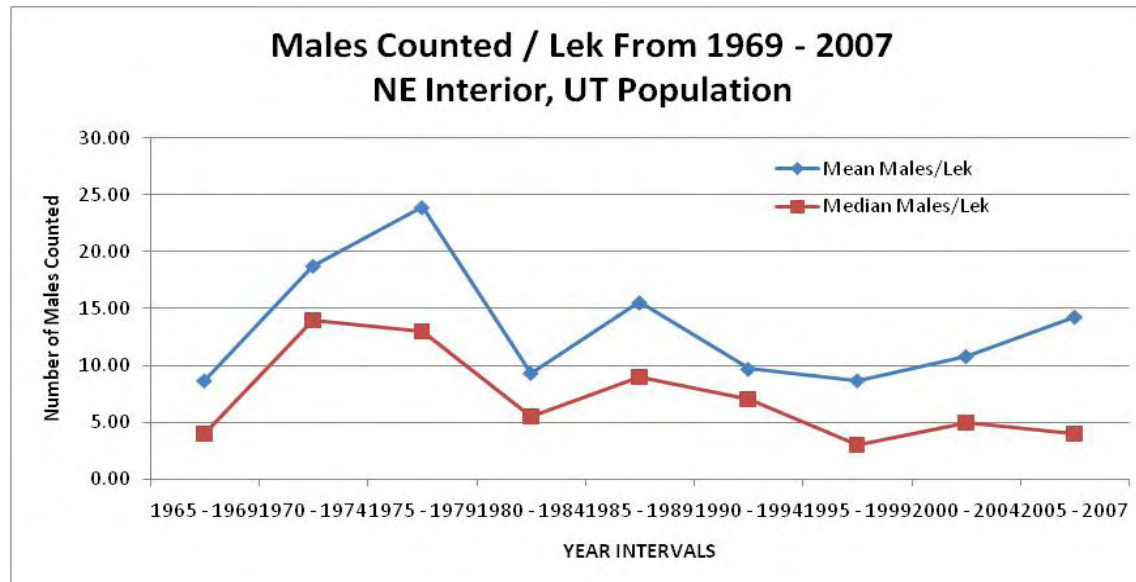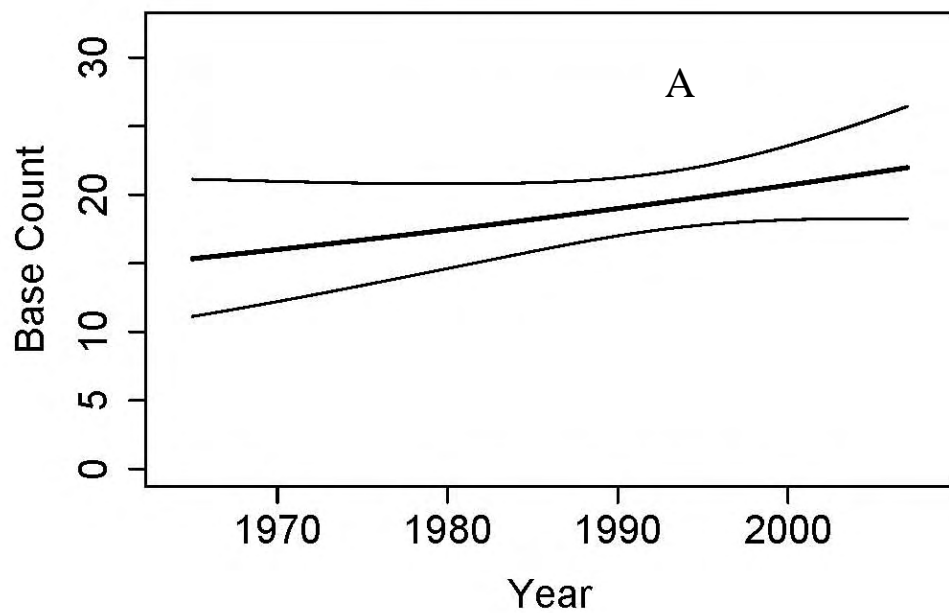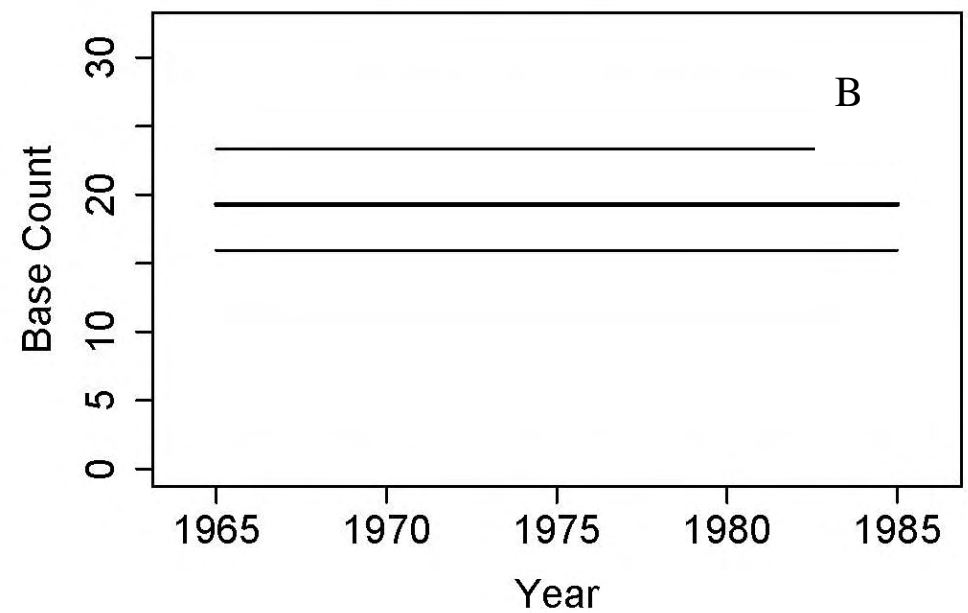

Figure D.6. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in Bannack, MT population.
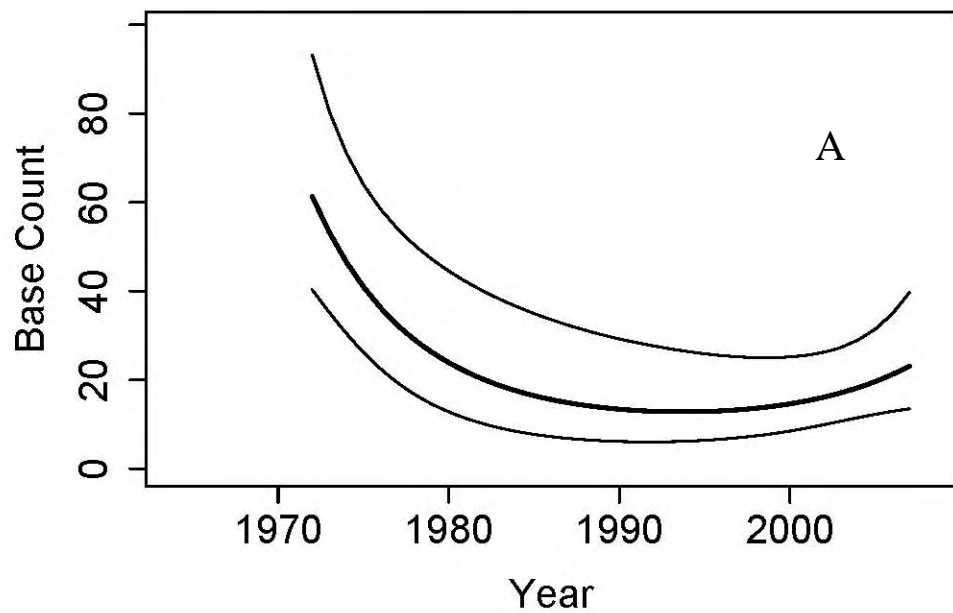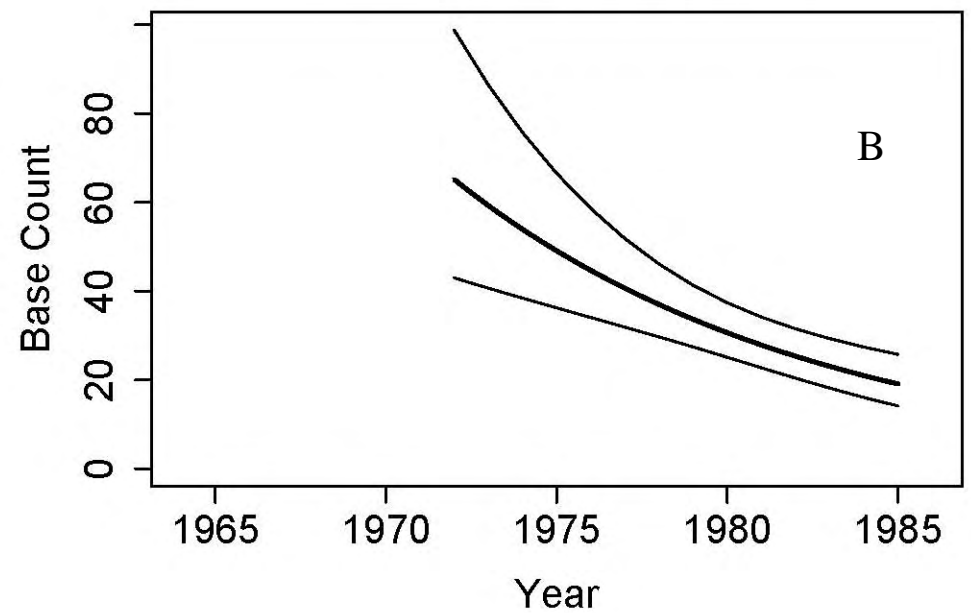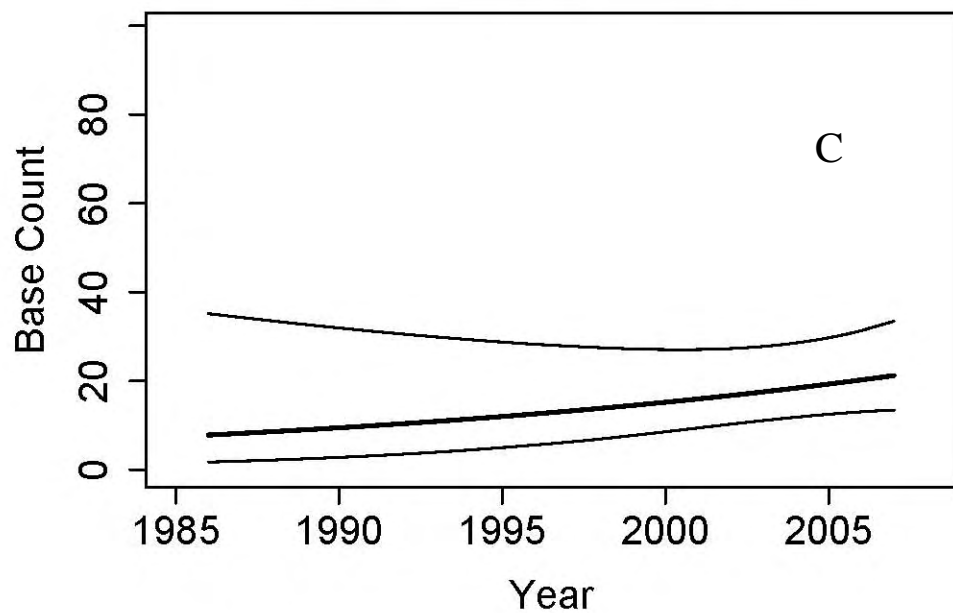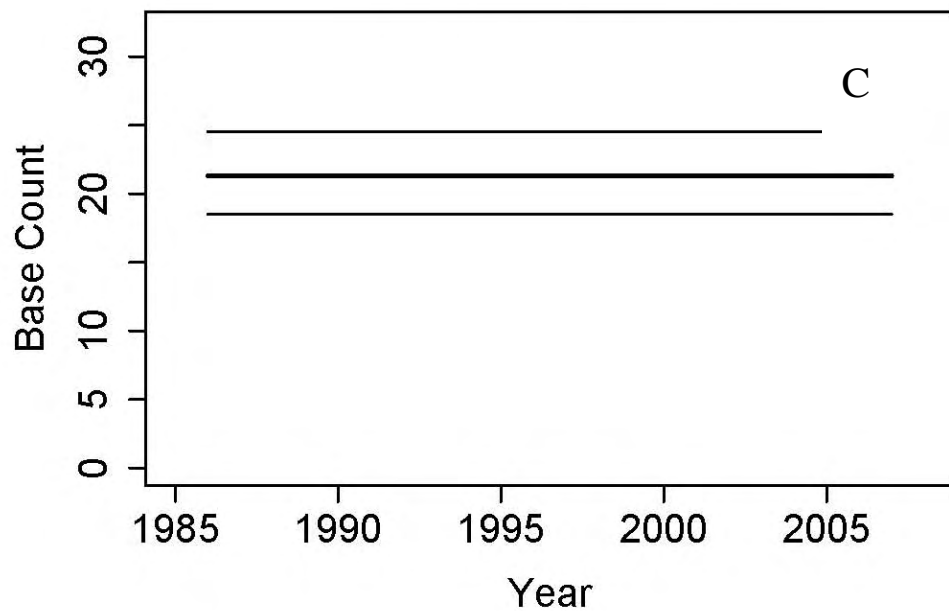
Figure D.7. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model for 1965 – 2007 (A) and linear models for 1965 – 1985 (B) and 1986 – 2007 (C).
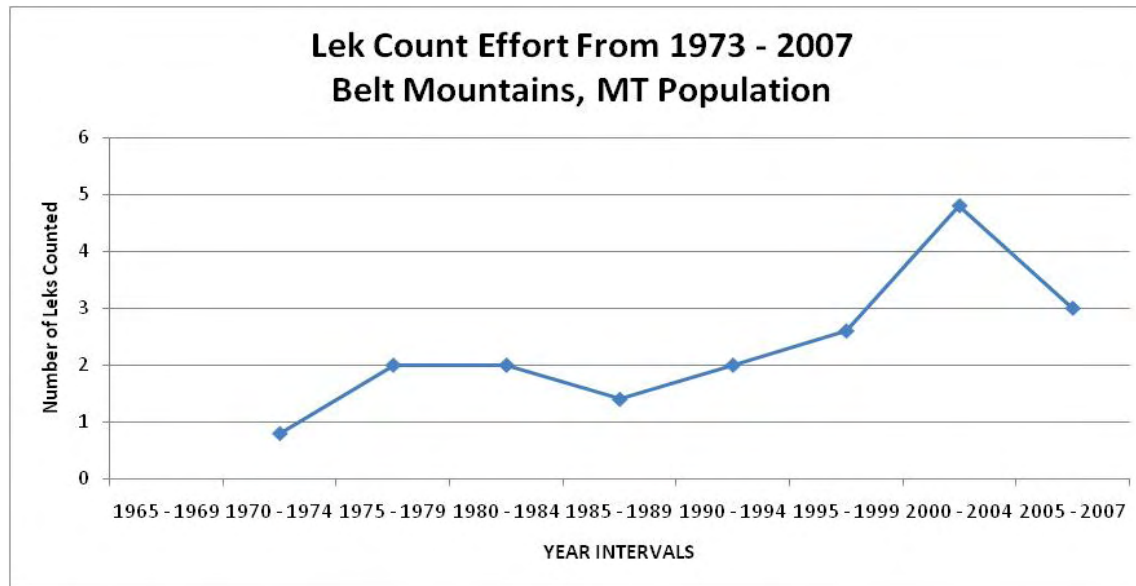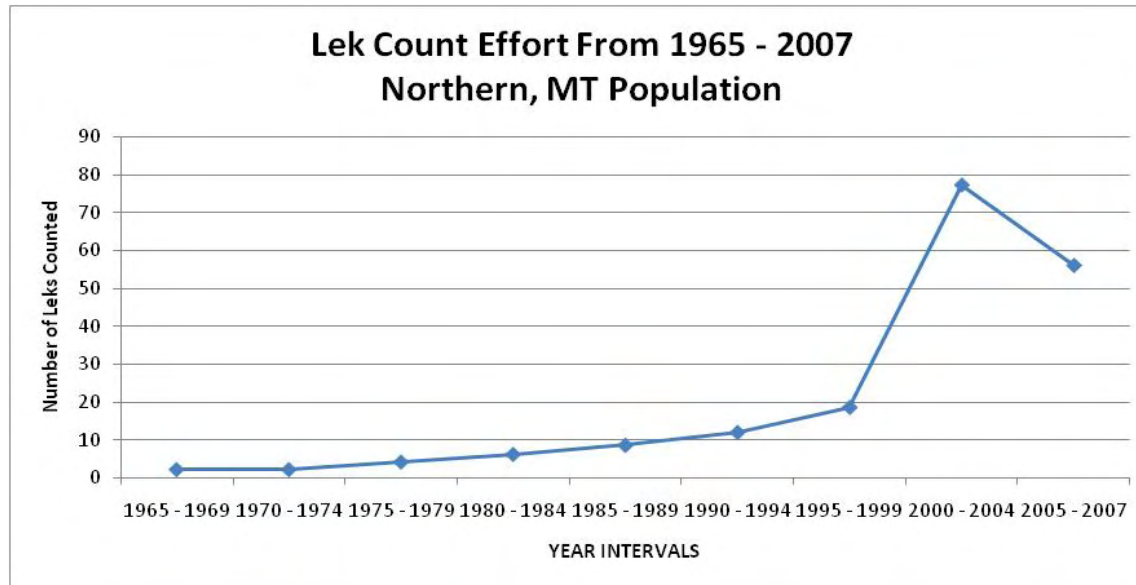
Figure D.8. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1973-2007 in the Belt Mountains, MT population.
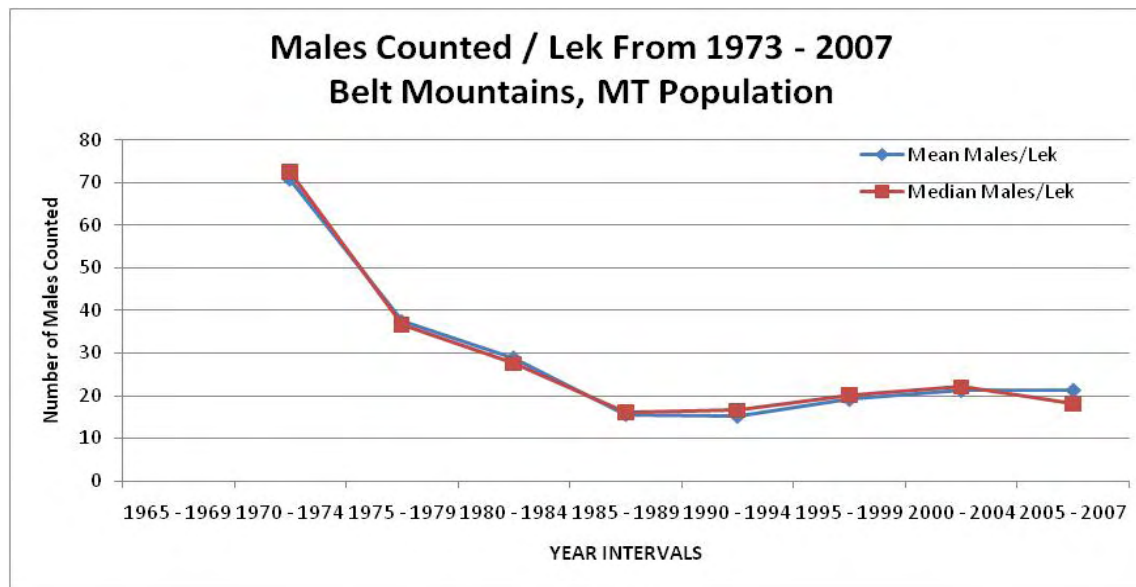
Figure D.9. The mean and median number of males counted on leks during time intervals from 1973 - 2007 in the Belt Mountains, MT population.
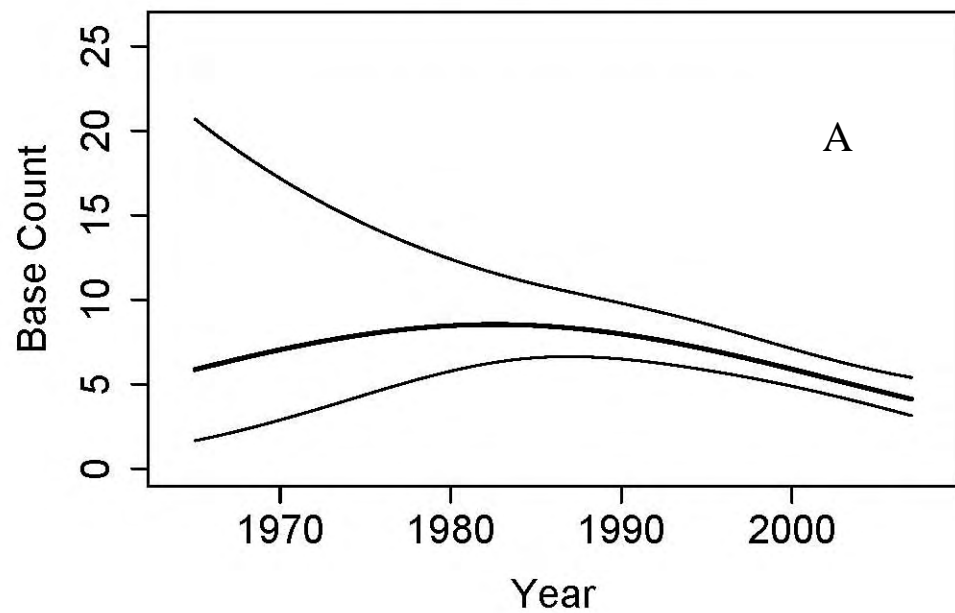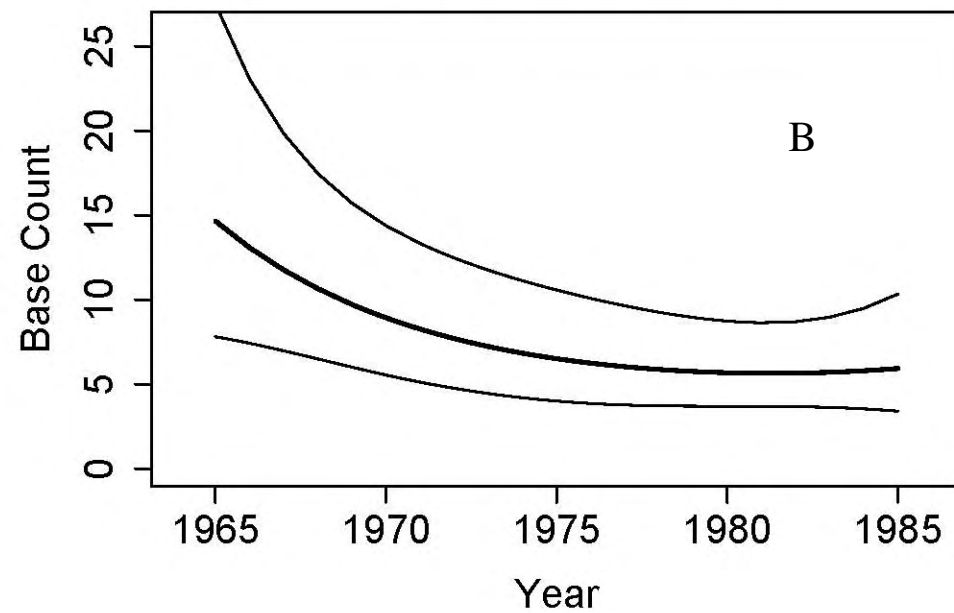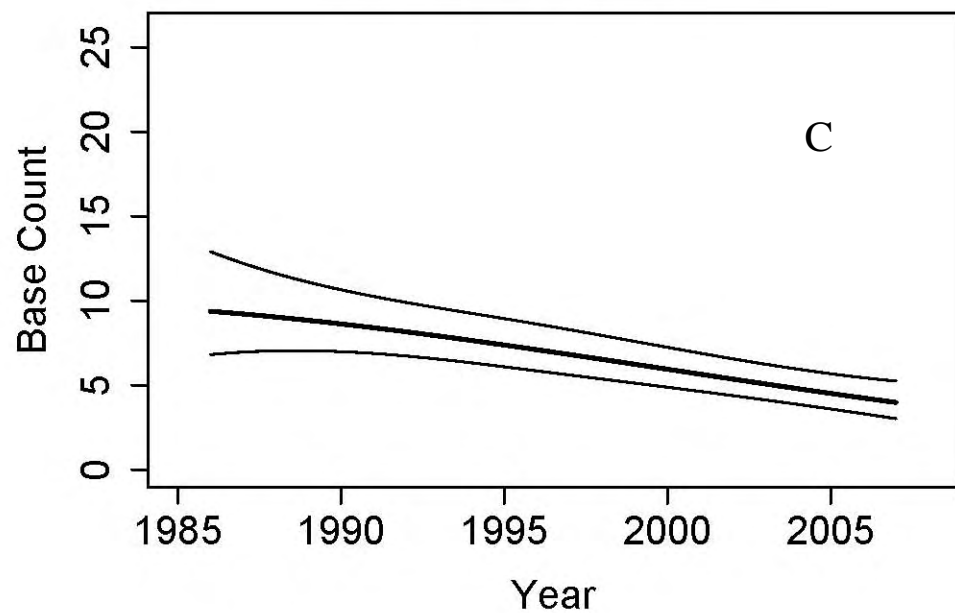
Figure D.10. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic models for 1965 – 2007 (A) 1965 – 1985 (B) and 1986 – 2007 (C).
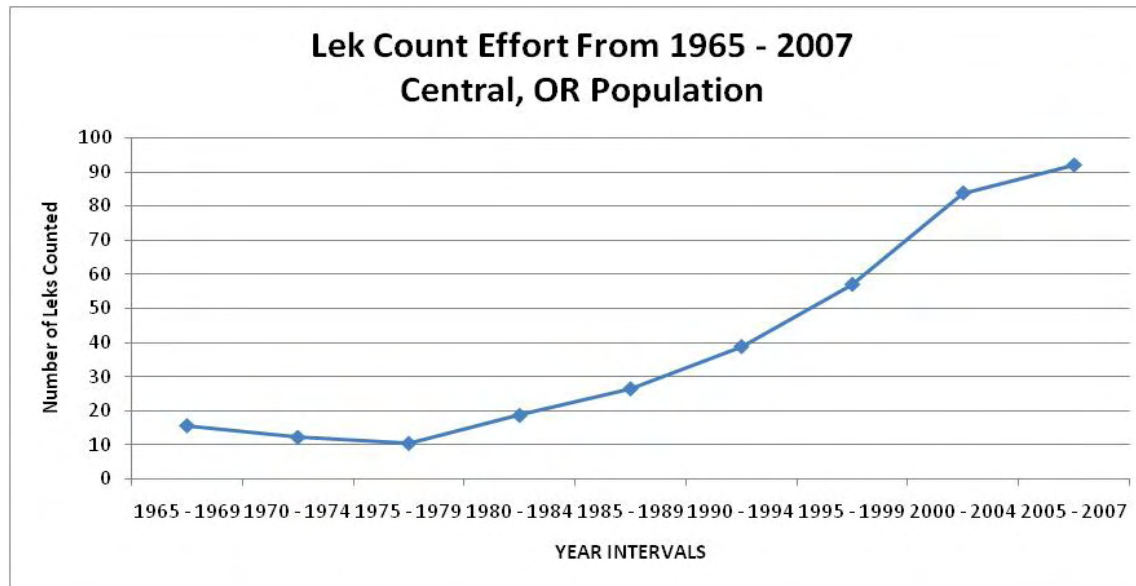
Figure D.11. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Central, OR population.
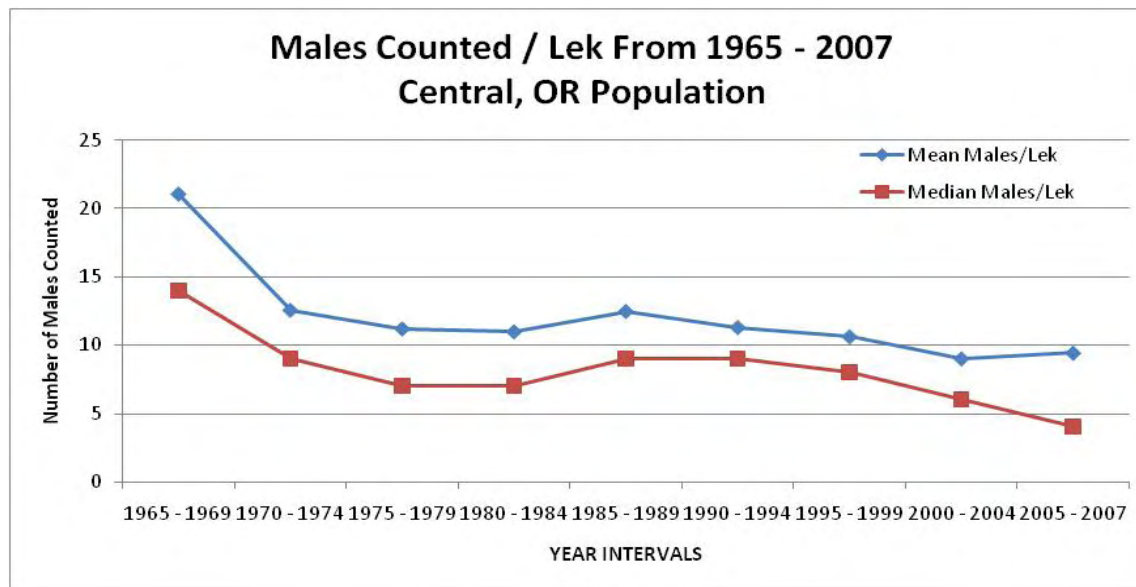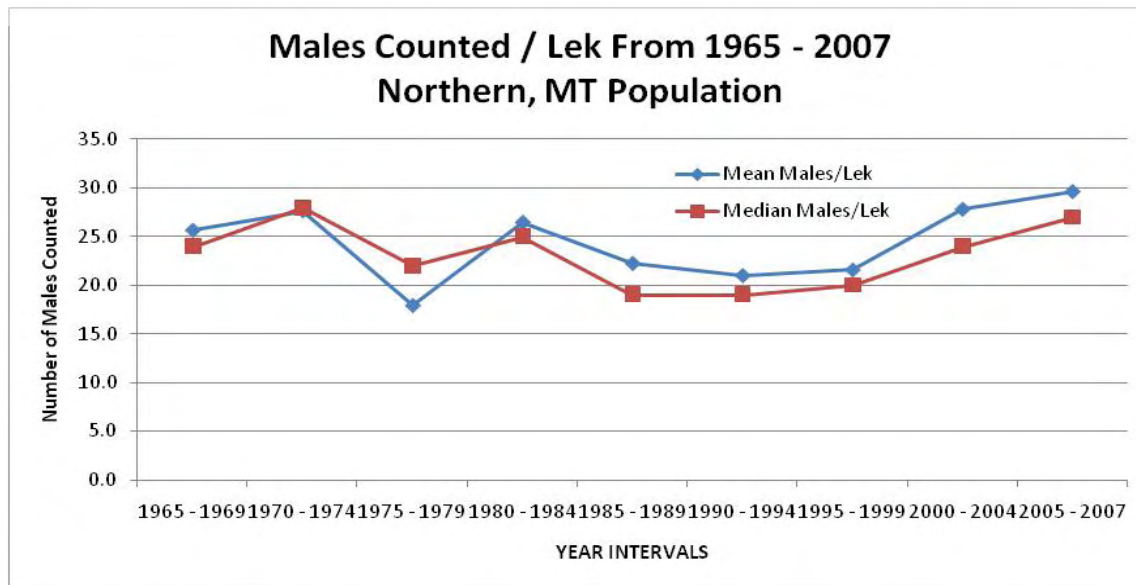

Figure D.12. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Central, OR population.
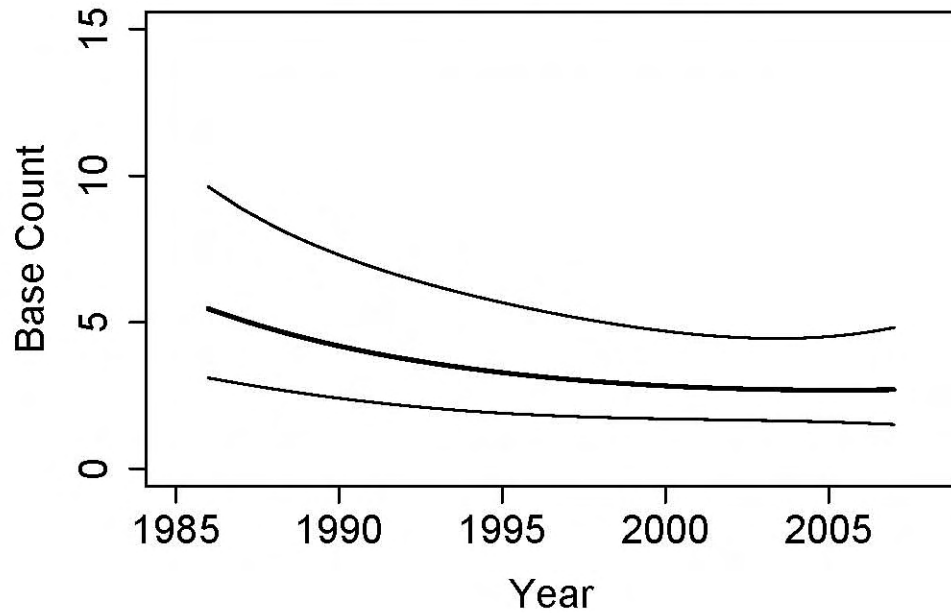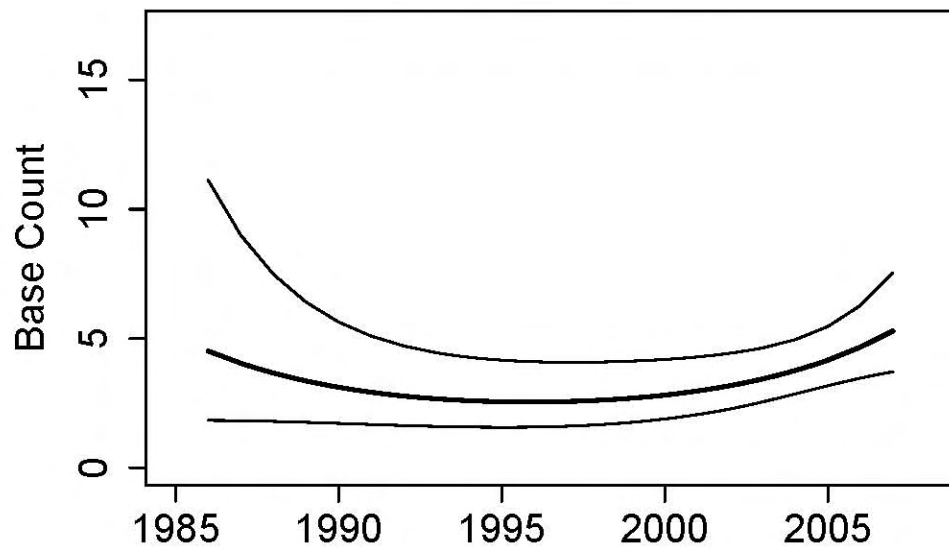
Figure D.13. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1986-2007 in the Eagle/S. Routt, CO population.
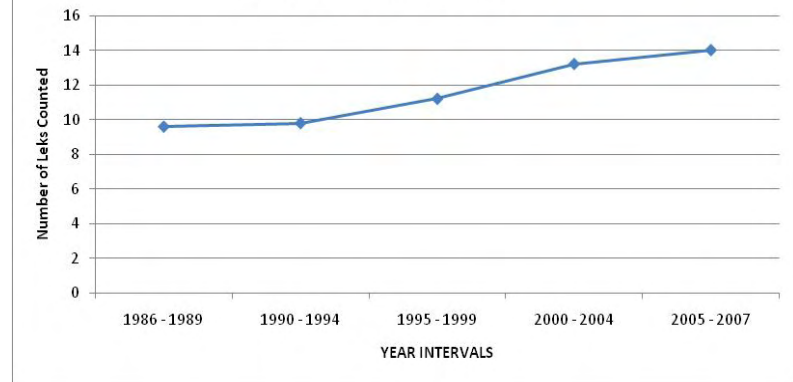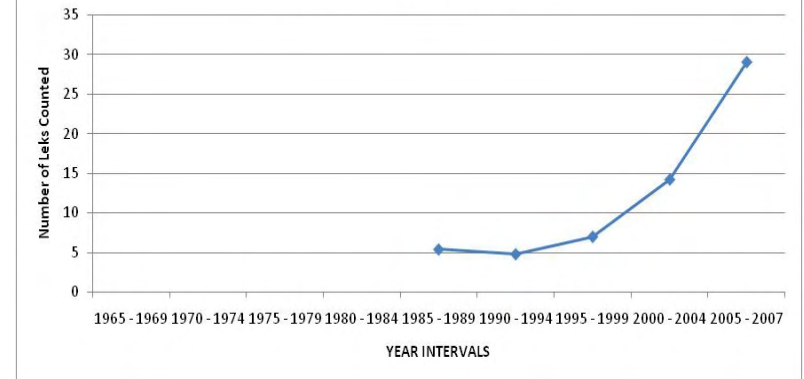

Figure D.14. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1986-2007 in the Eagle/S. Routt, CO population.
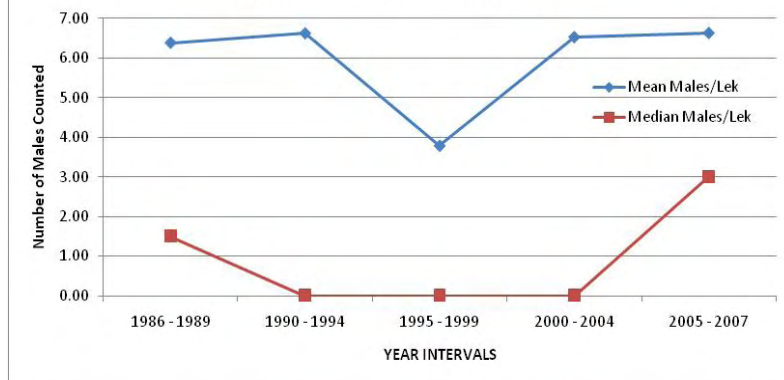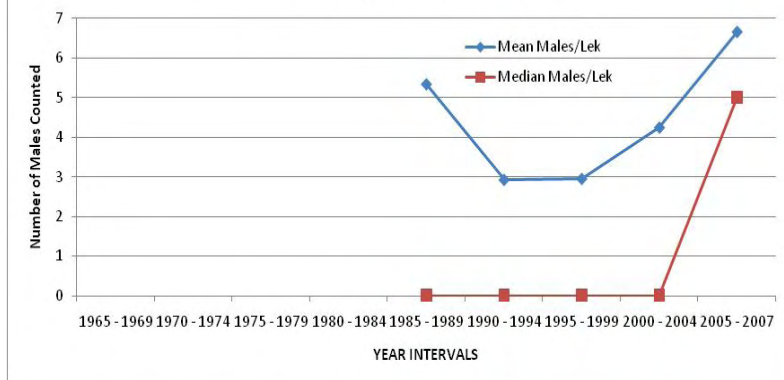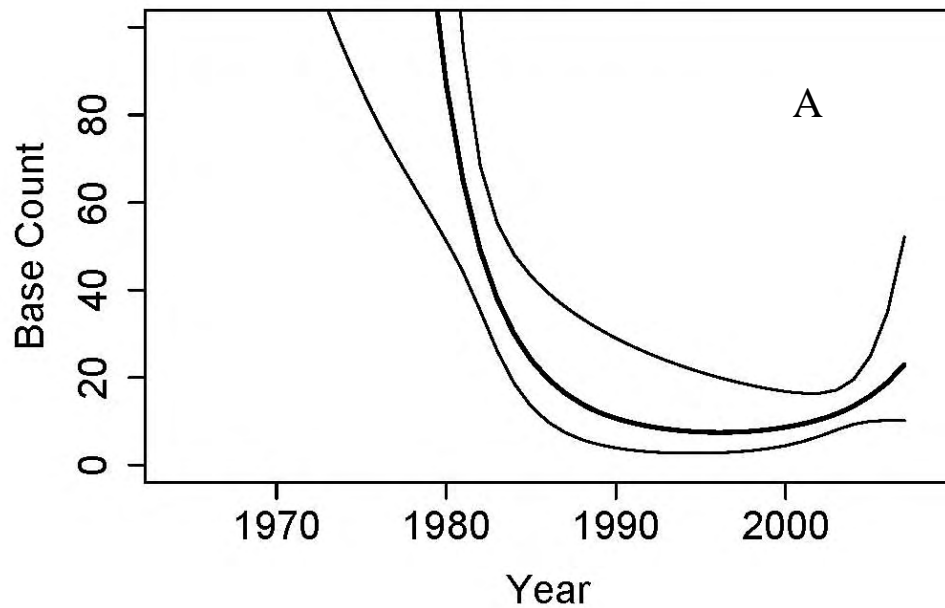

Figure D.15. The mean and median number of males counted on leks during time intervals from 1986 - 2007 in the Eagle/S. Routt, CO population.
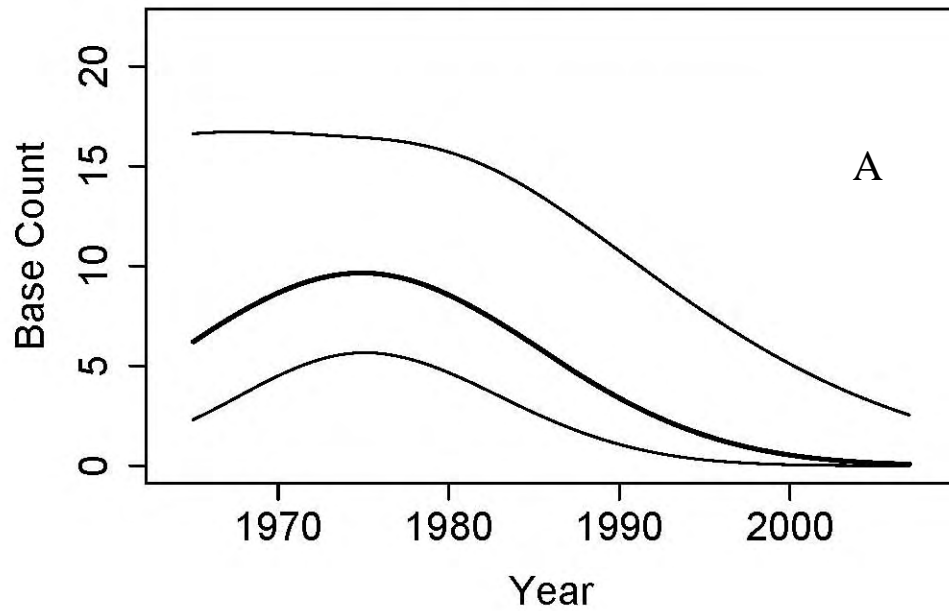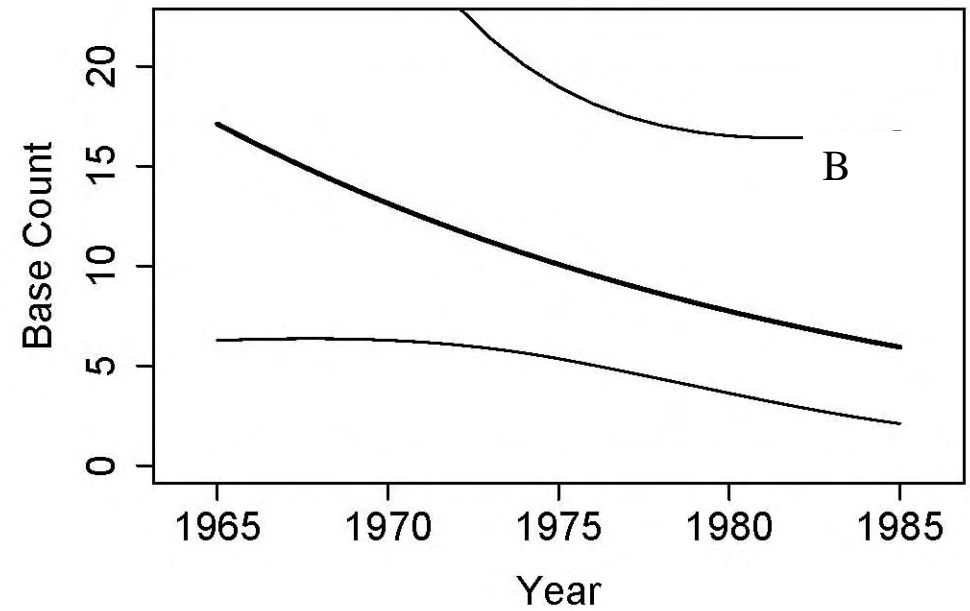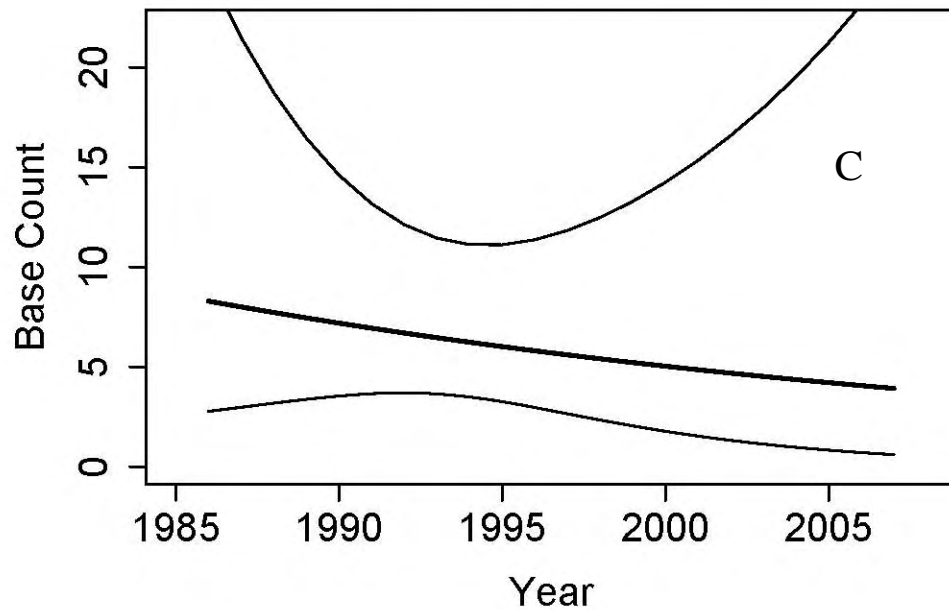
Figure D.16. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model for 1965 – 2007 (A) and linear models for 1965 – 1985 (B) and 1986 – 2007 (C).
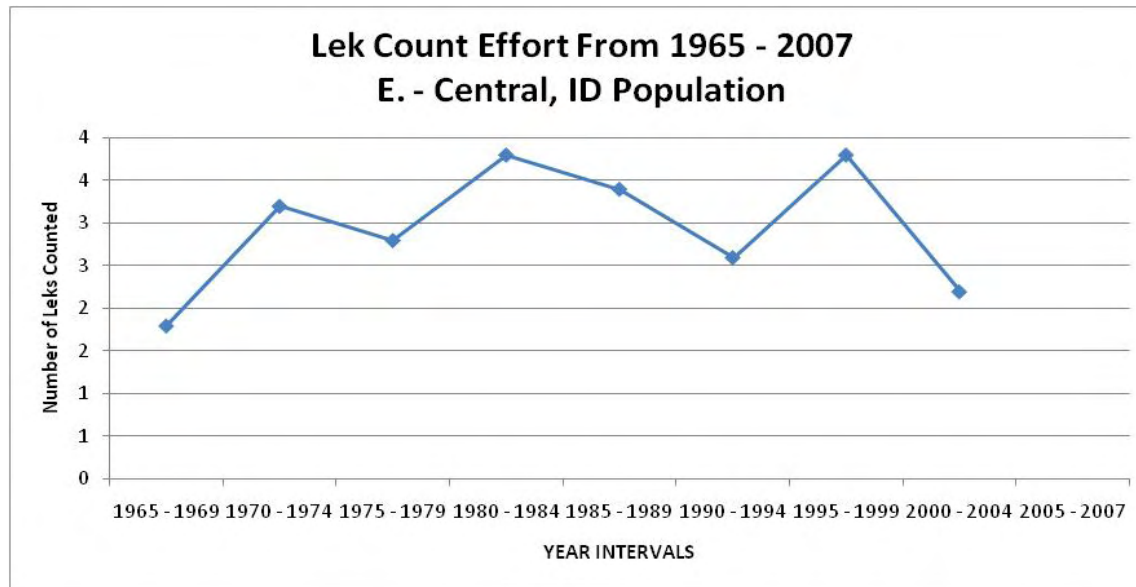
Figure D.17. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the E-Central, ID population.
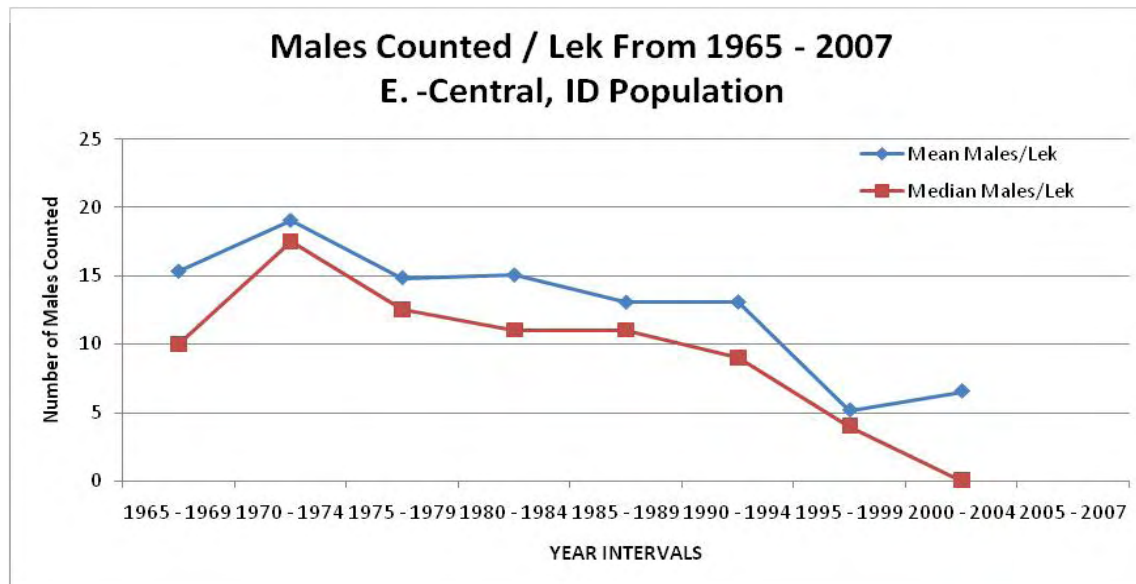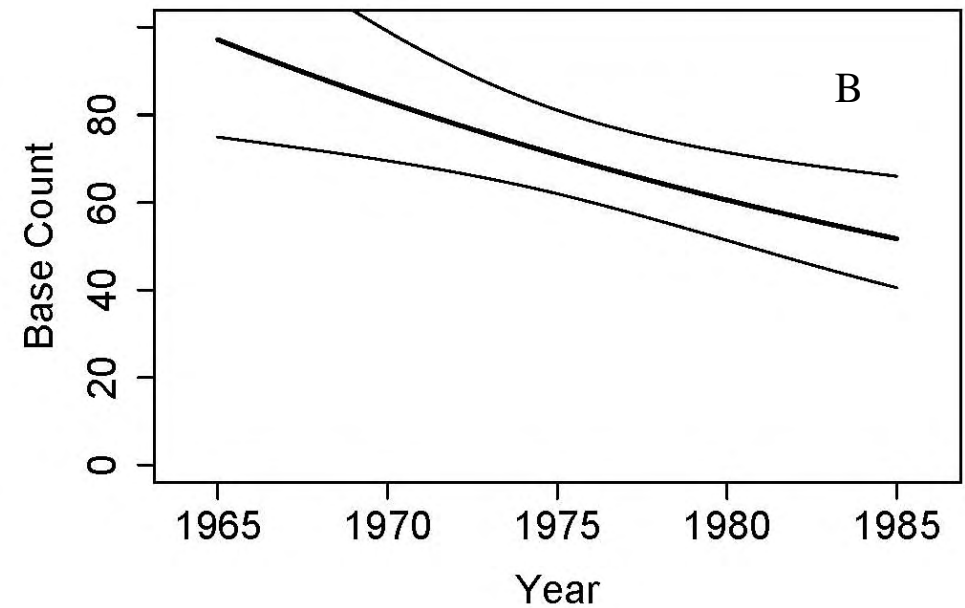

Figure D.18. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the E-Central, ID population.
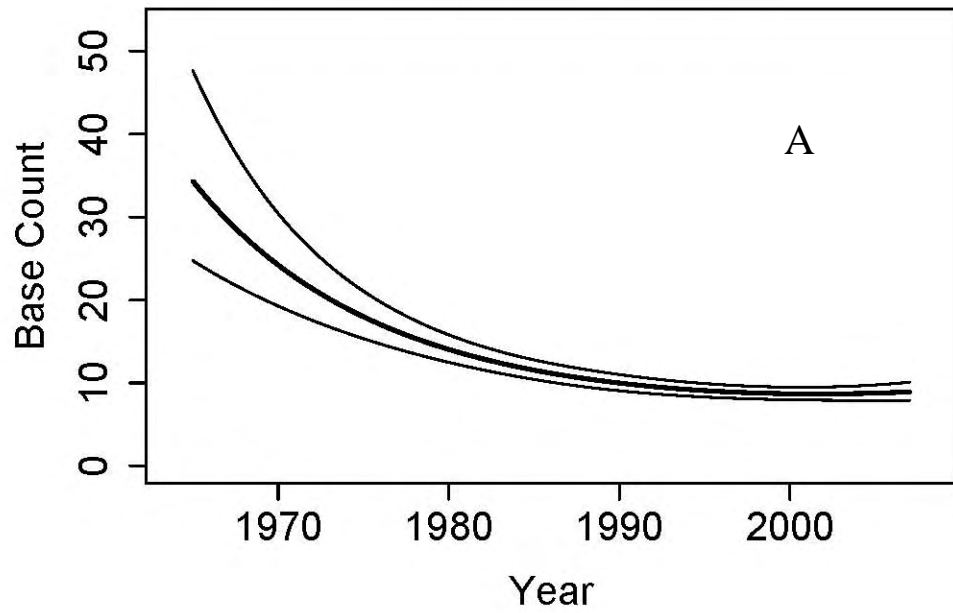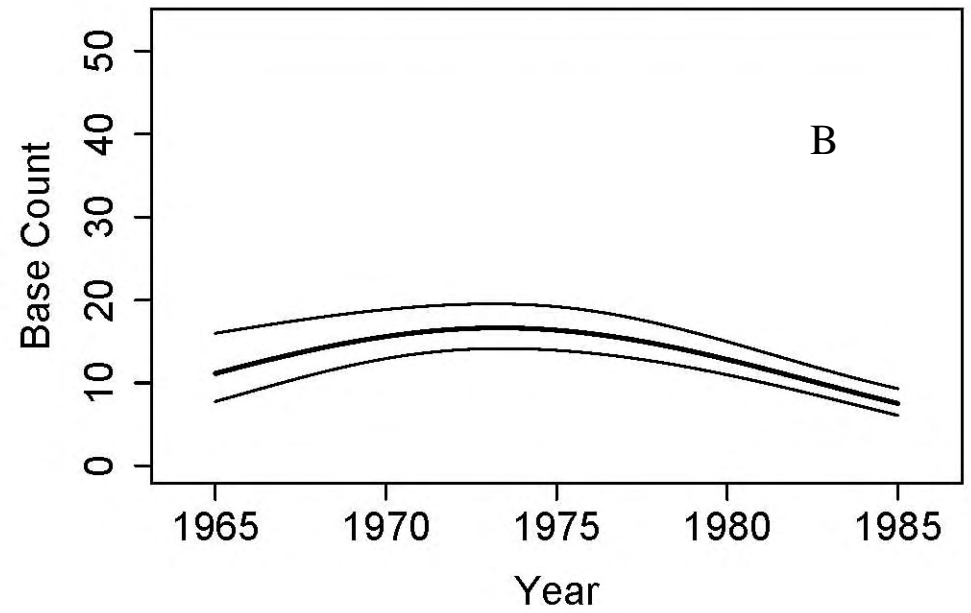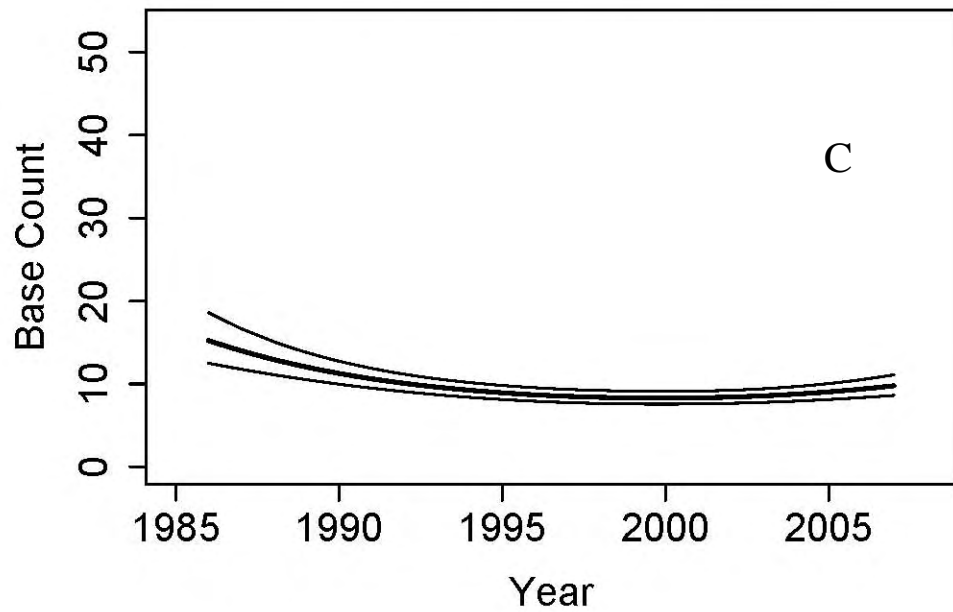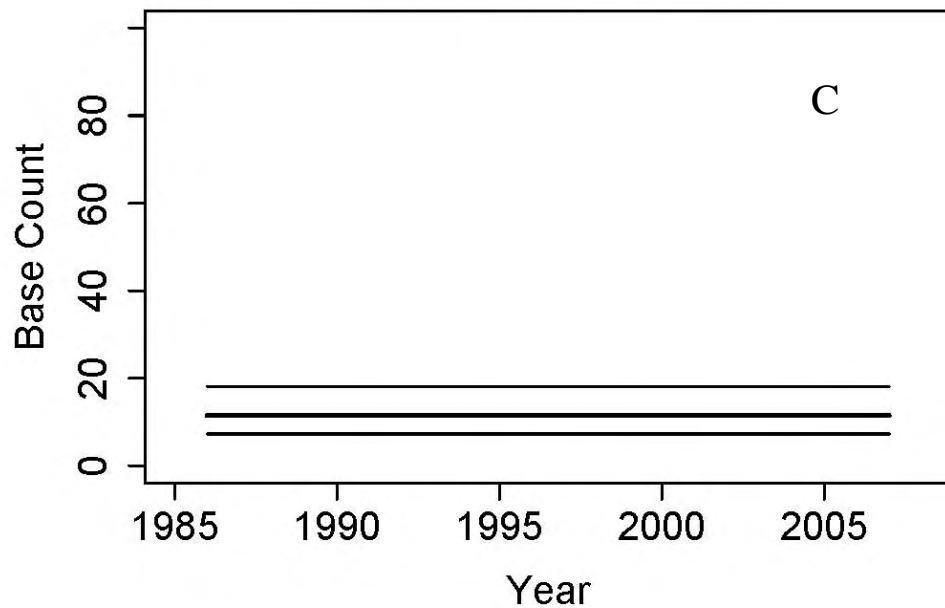
Figure D.19. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic models for 1965 – 2007 (A), 1965 – 1985 (B), and 1986 – 2007 (C).
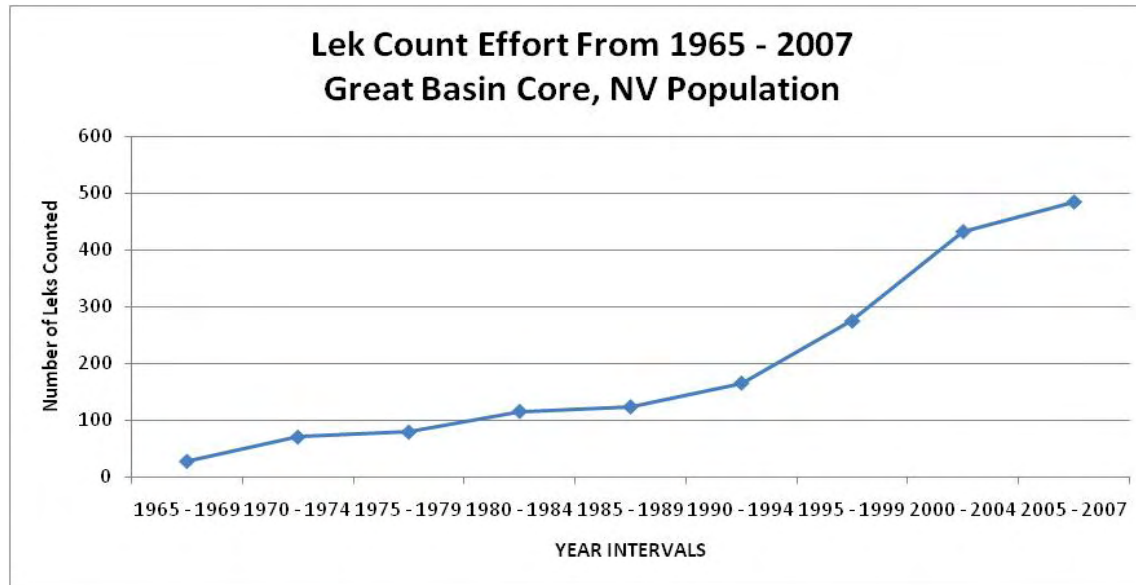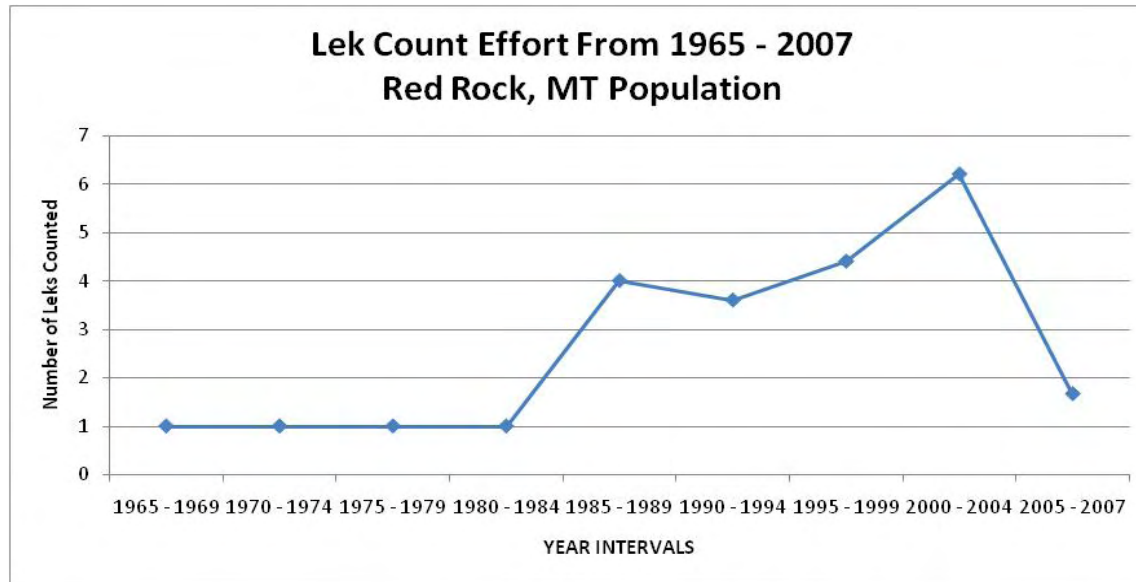
Figure D.20. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Great Basin Core, NV population.
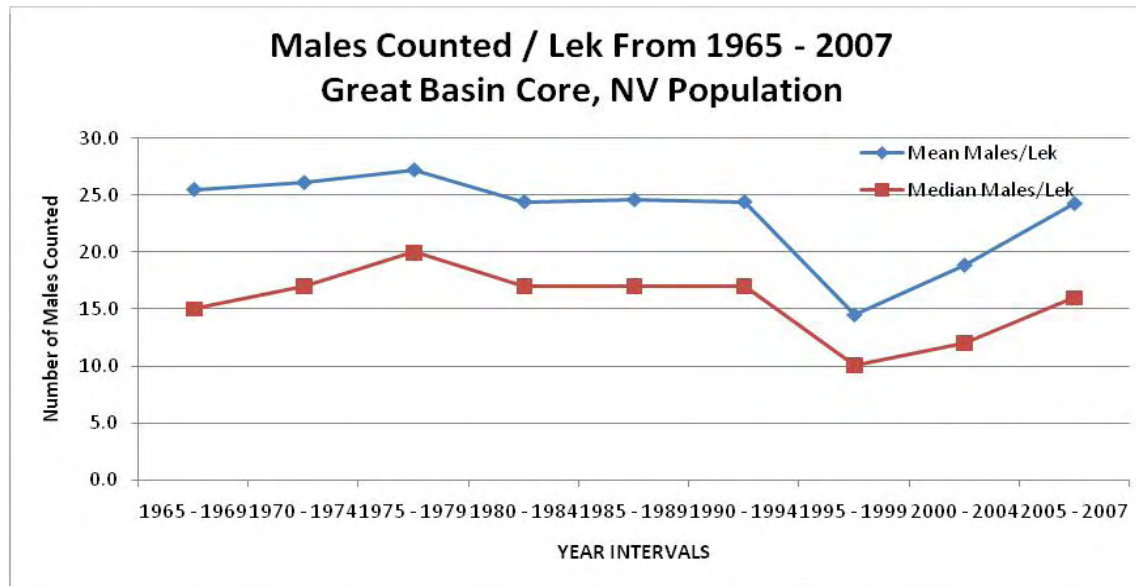
Figure D.21. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Great Basin Core, NV population.
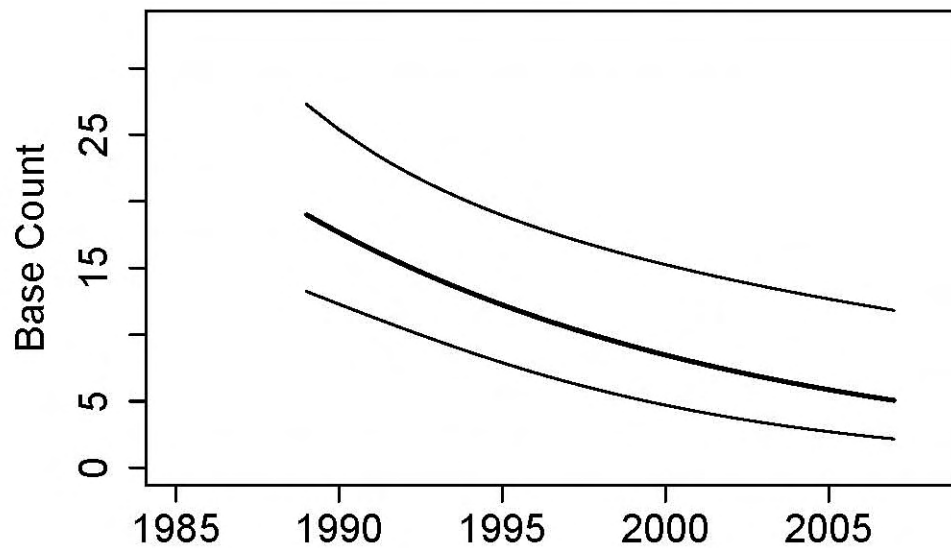
Figure D.22. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1989-2007 in the Jackson Hole, WY population.
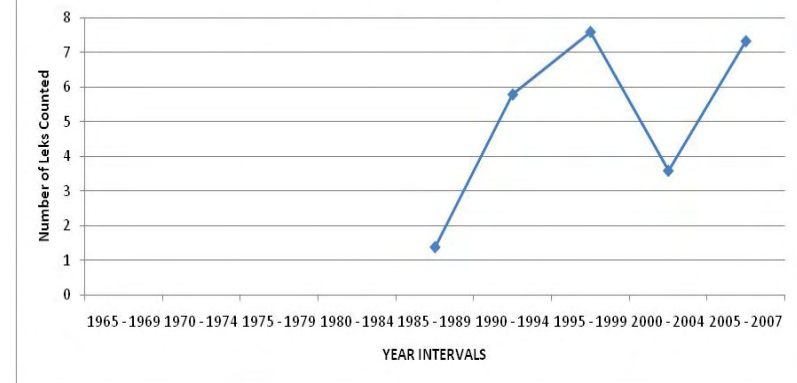
Figure D.23. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1989-2007 in the Jackson Hole, WY population.
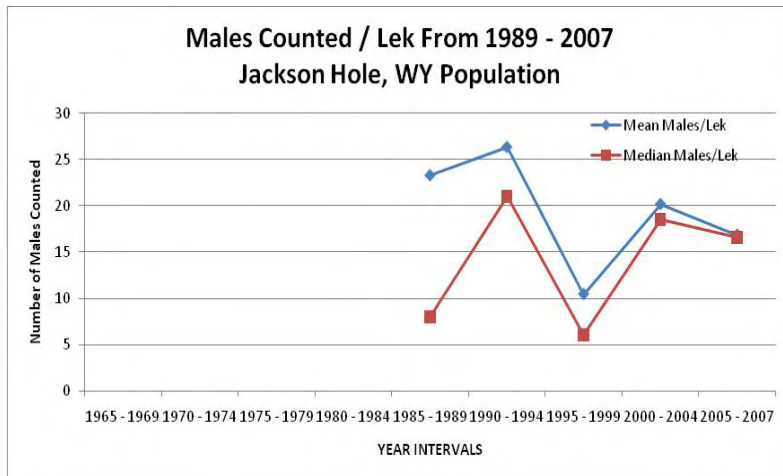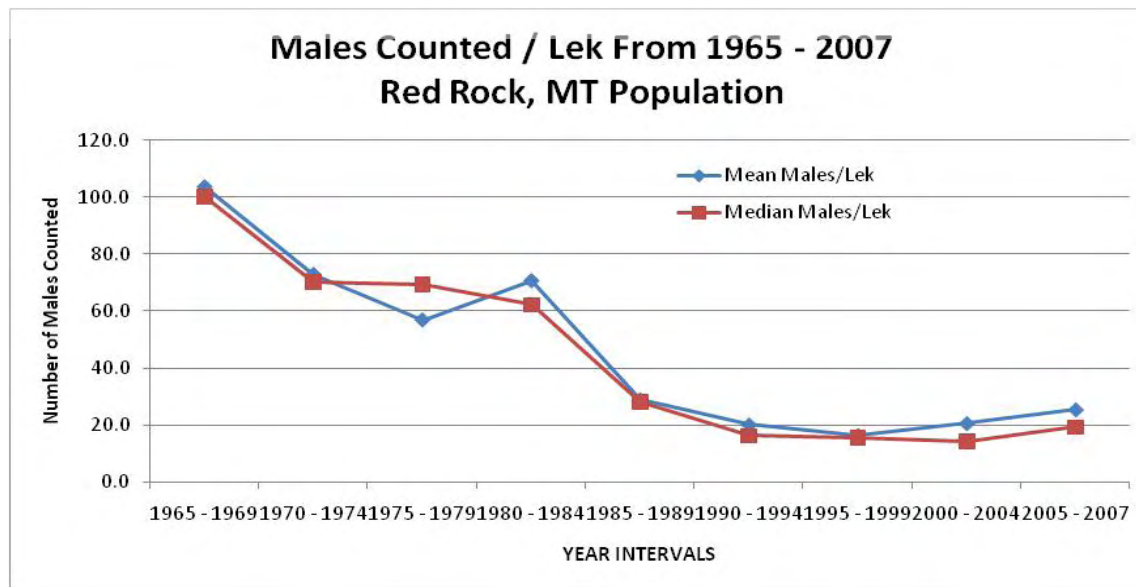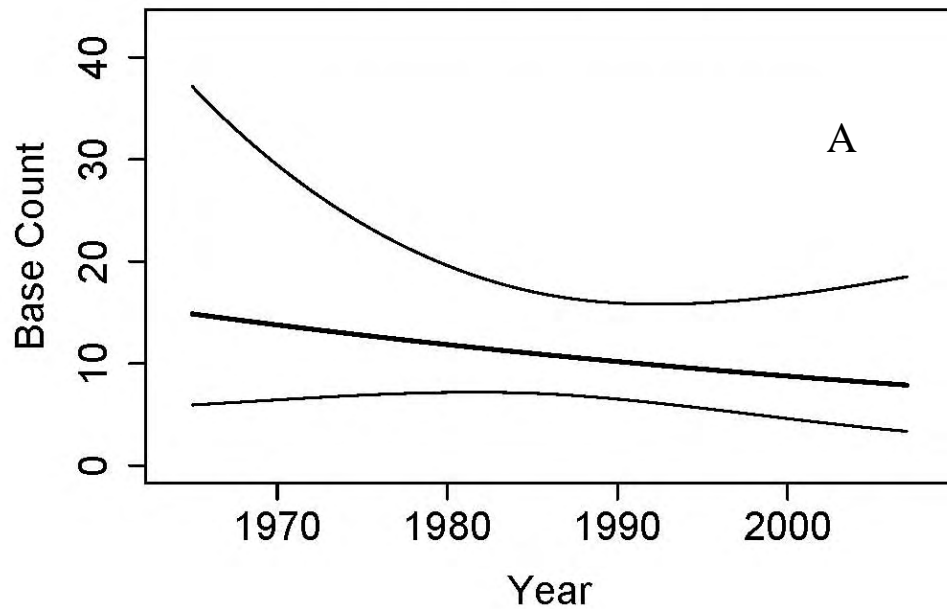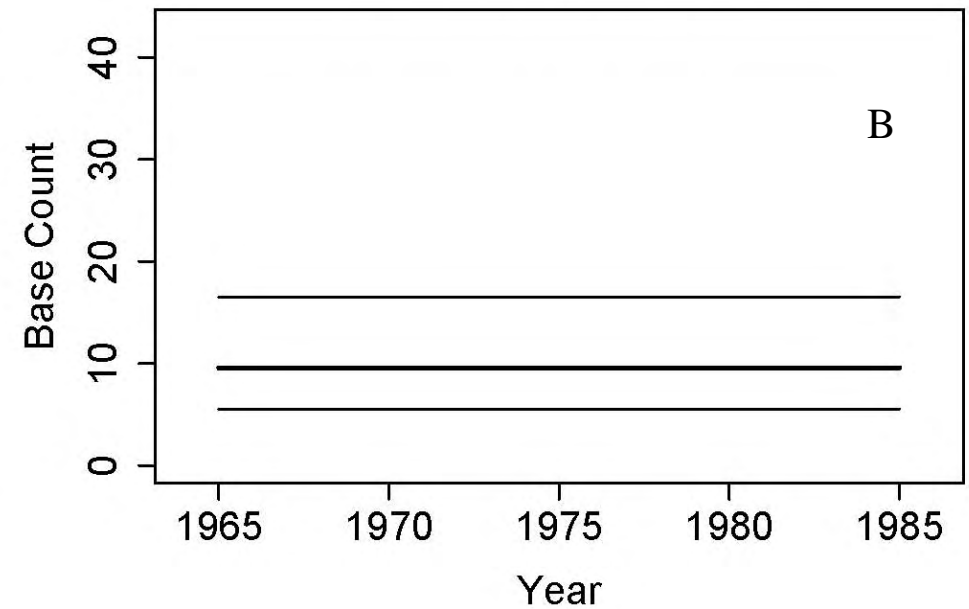

Figure D.24. The mean and median number of males counted on leks during time intervals from 1989 - 2007 in the Jackson Hole, WY population.
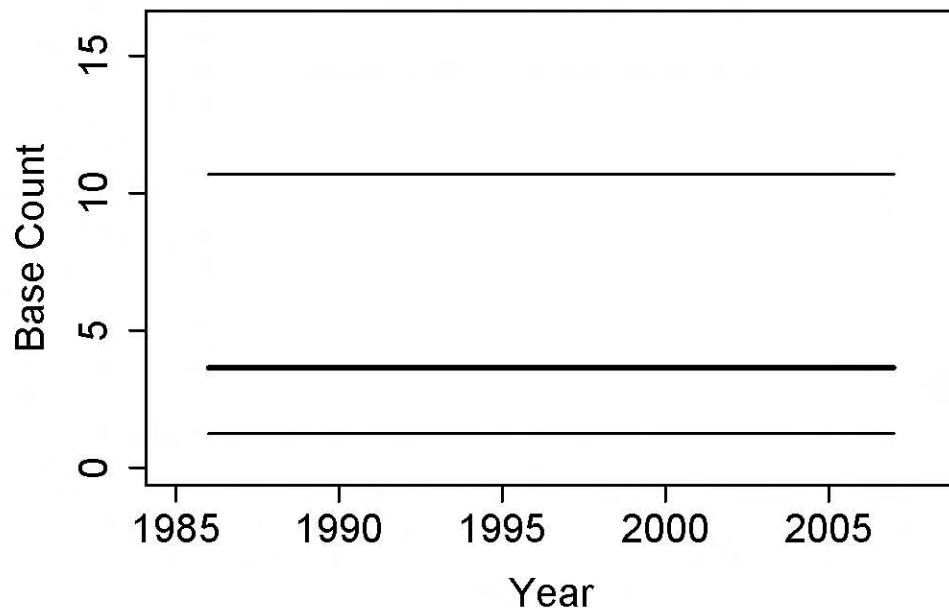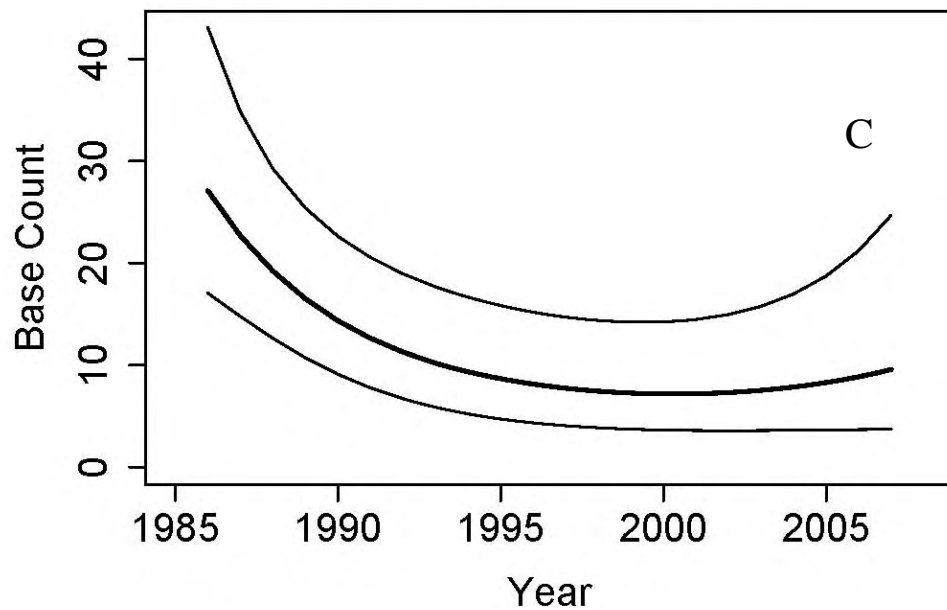
Figure D.25. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model.
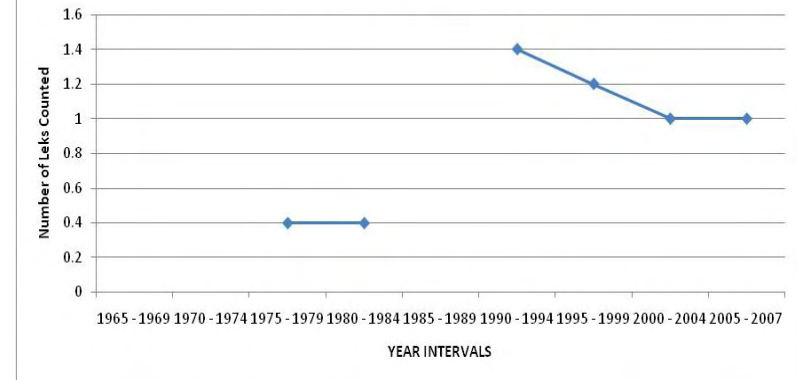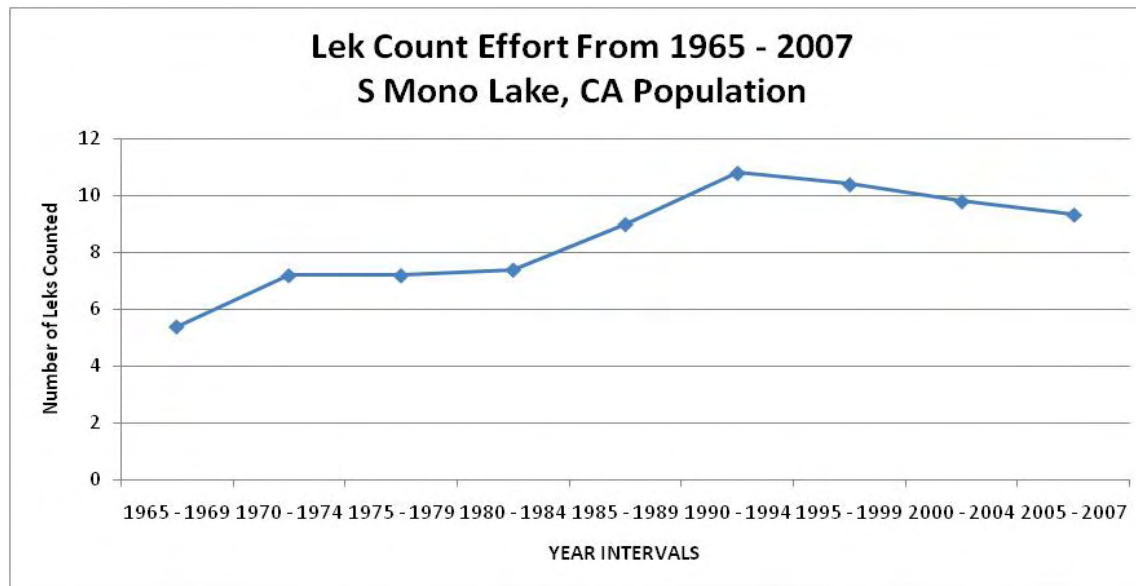

Figure D.26. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1977-2007 in the Klamath, OR population.
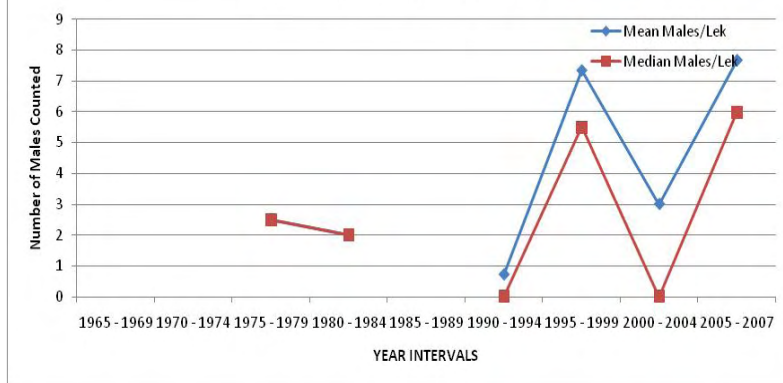
Figure D.27. The mean and median number of males counted on leks during time intervals from 1977 - 2007 in the Klamath, OR population.

Laramie WY 1965−2007

A
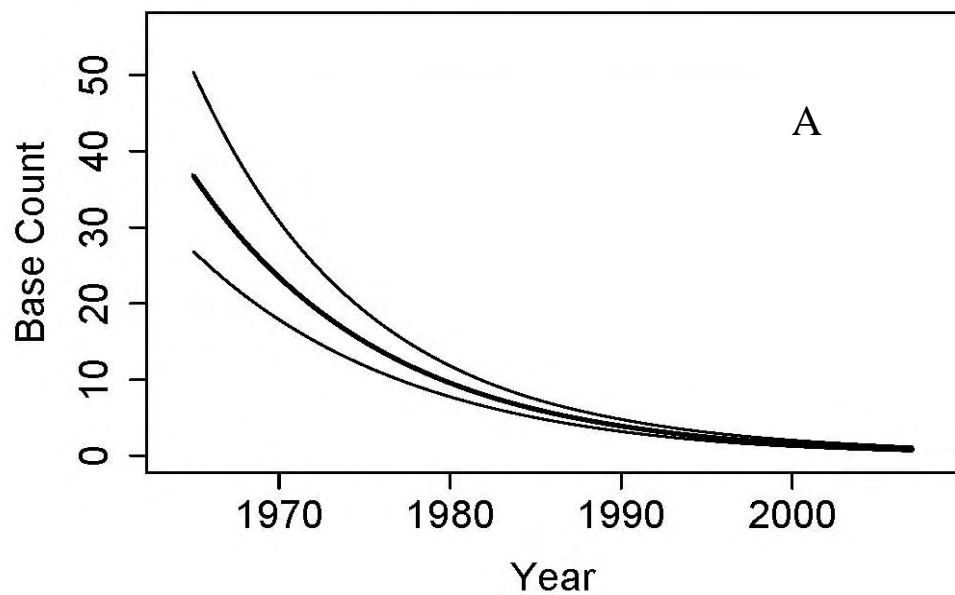
Laramie WY 1965−1985

B
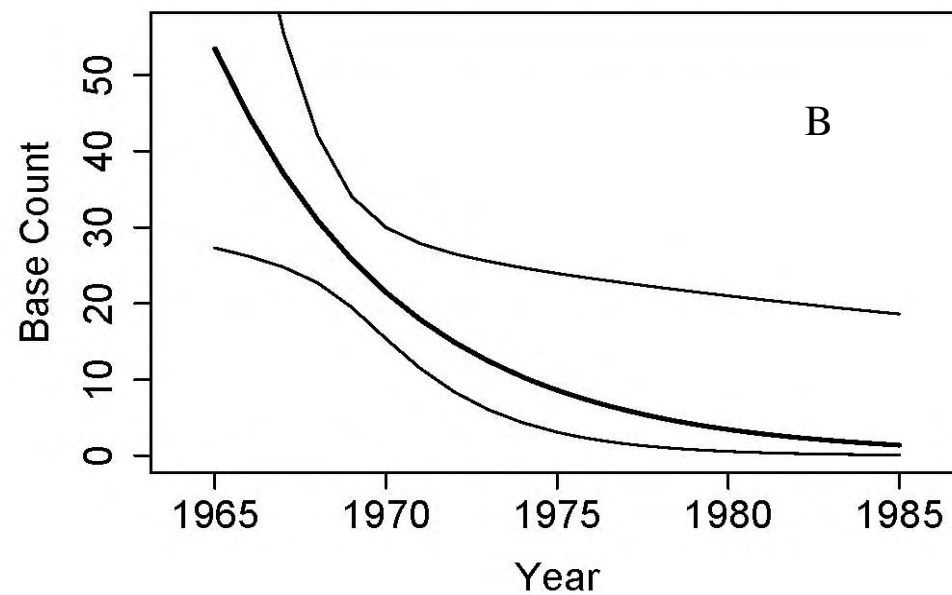
Laramie WY 1986−2007

C
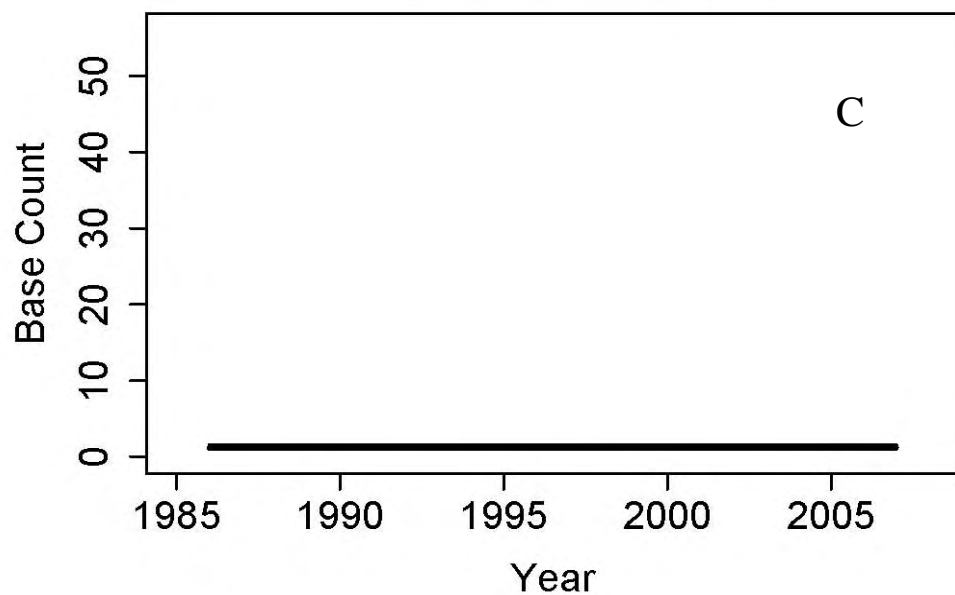
Figure D.28. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear models for 1965 – 2007 (A) and 1965 – 1985 (B), and the constant model for 1986 – 2007 (C).
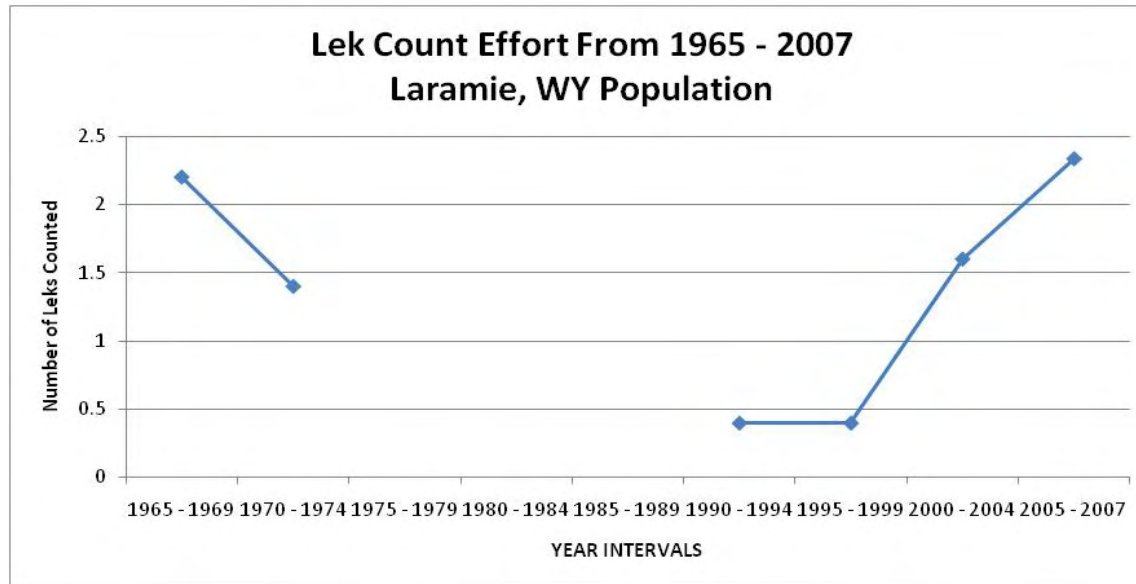
Figure D.29. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Laramie, WY population.
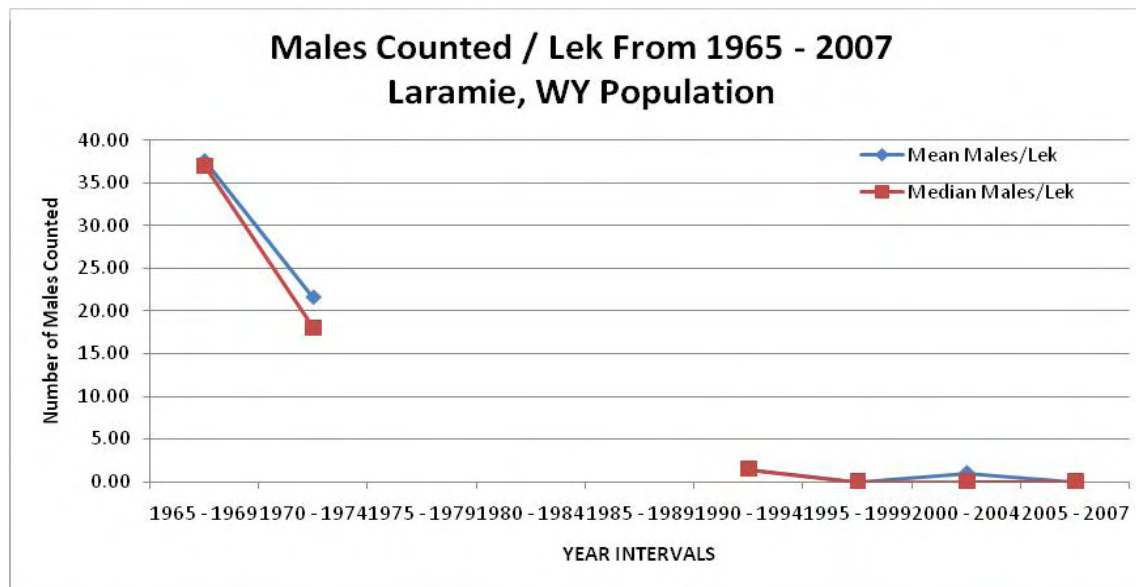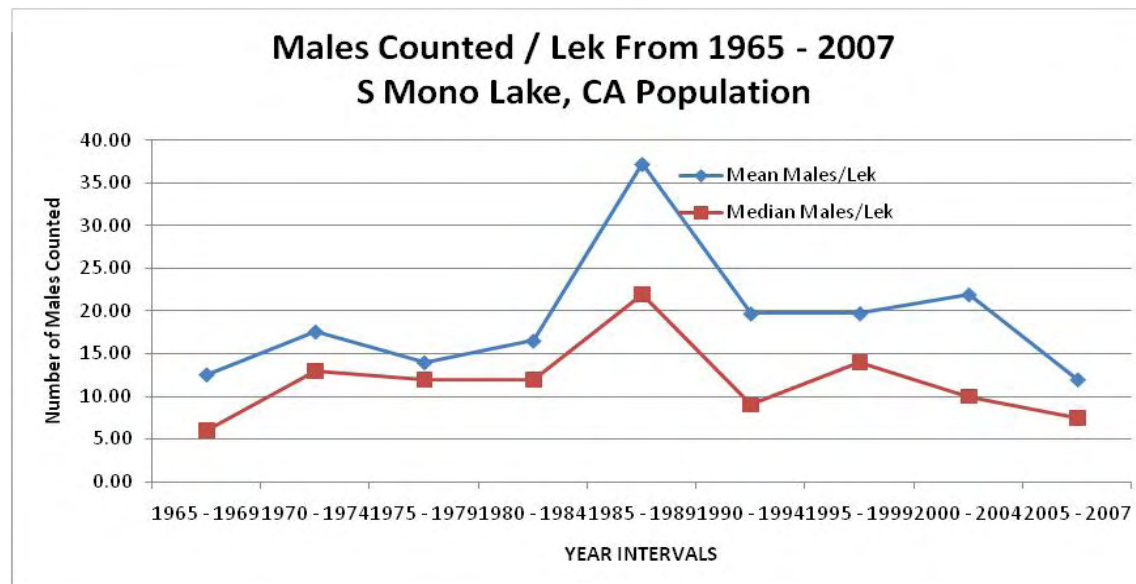

Figure D.30. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Laramie, WY population.
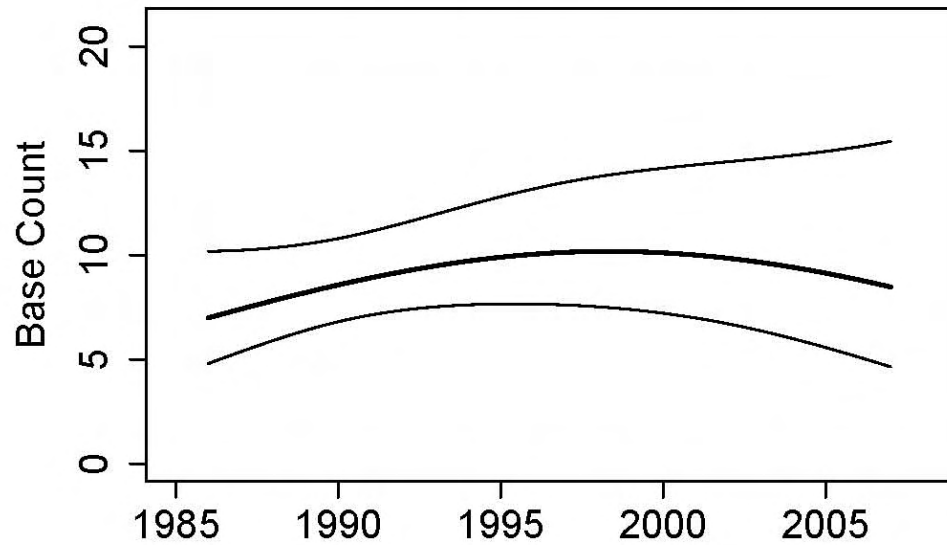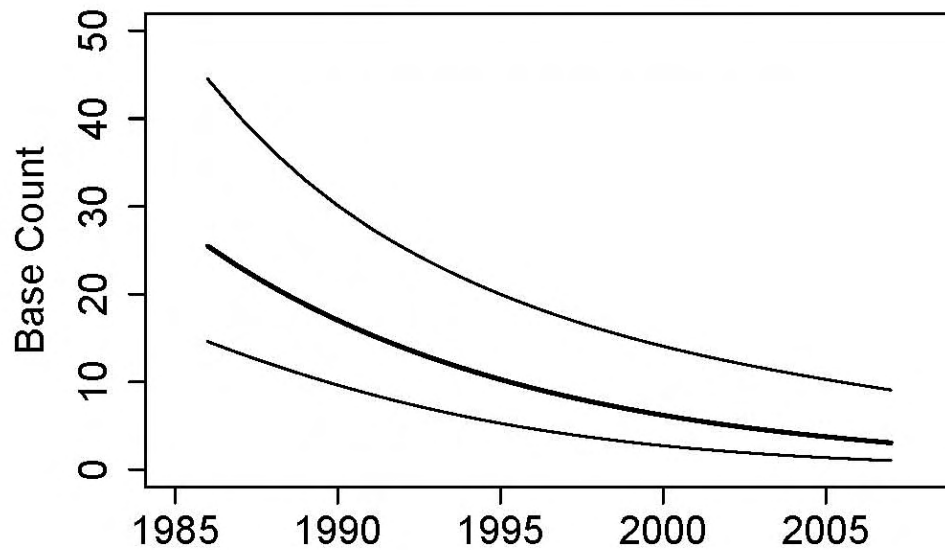
Figure D.31. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1986-2007 in the Middle Park, CO population.
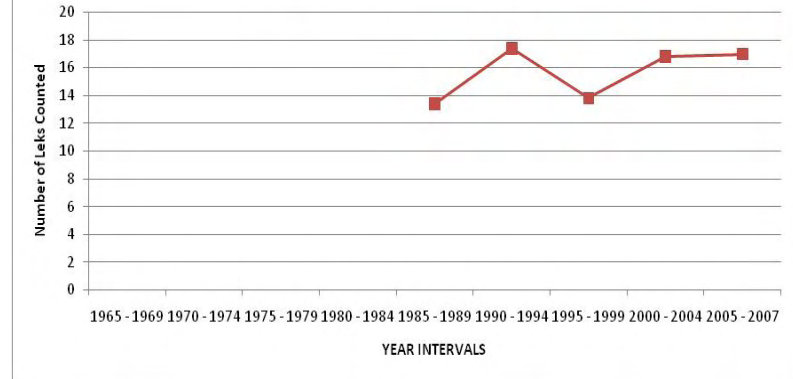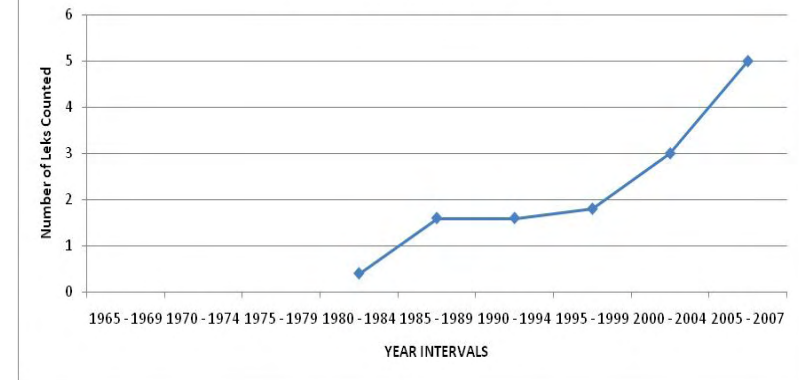

Figure D.32. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1986-2007 in the Middle Park, CO population.
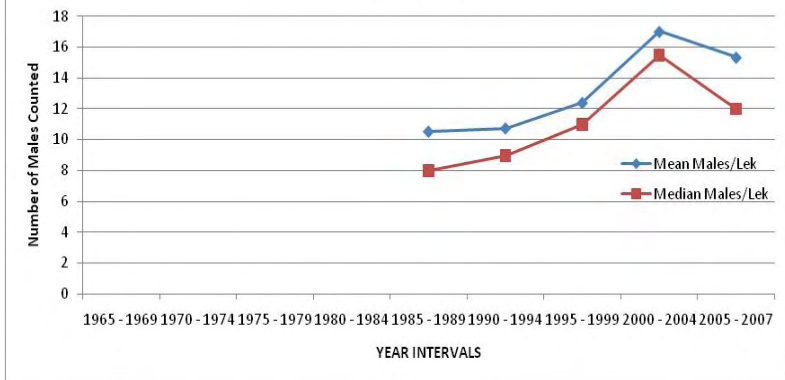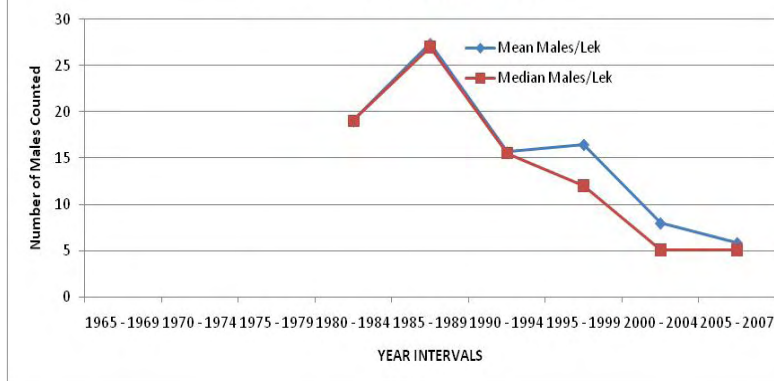

Figure D.33. The mean and median number of males counted on leks during time intervals from 1986 - 2007 in the Middle Park, CO population.
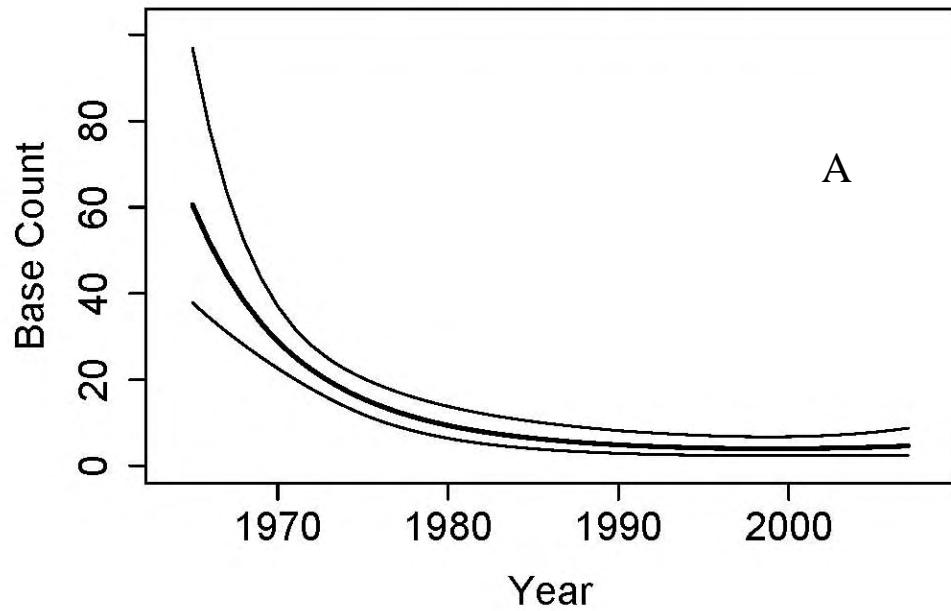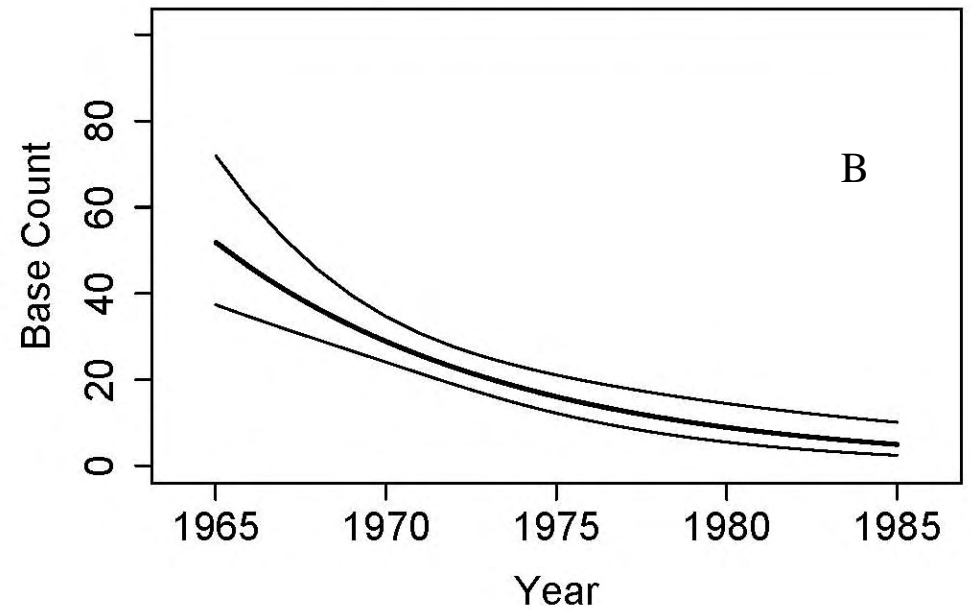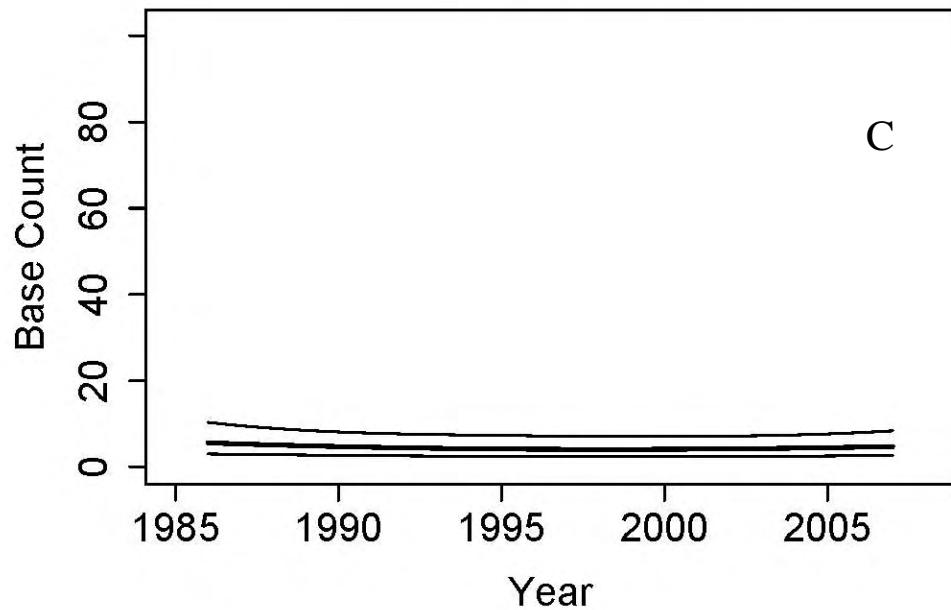
Figure D.34. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model for 1965 – 2007 (A), the linear model for 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).
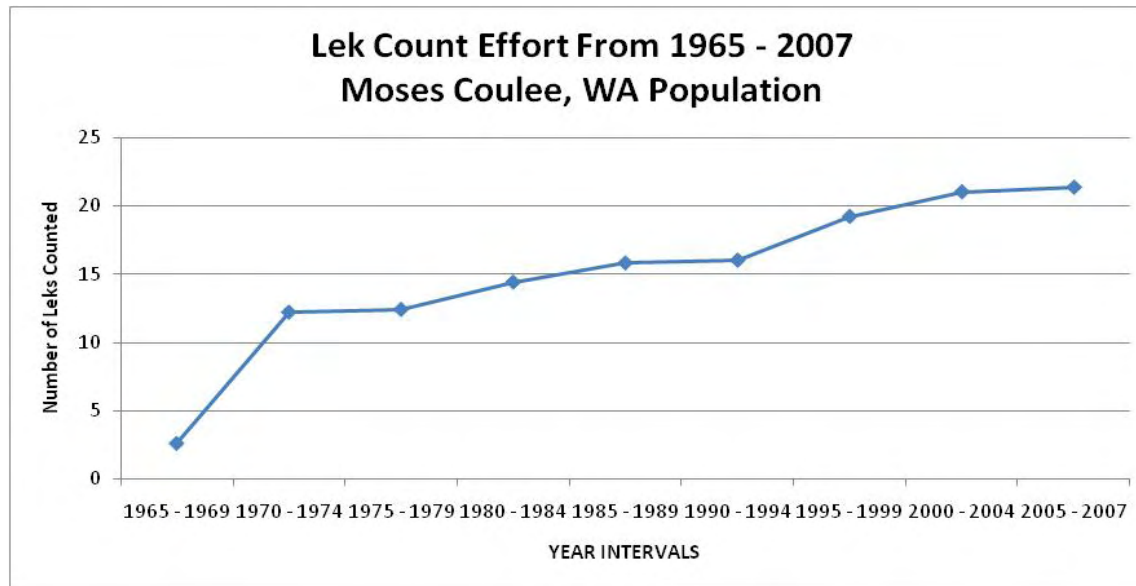
Figure D.35. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Moses Coulee, WA population.
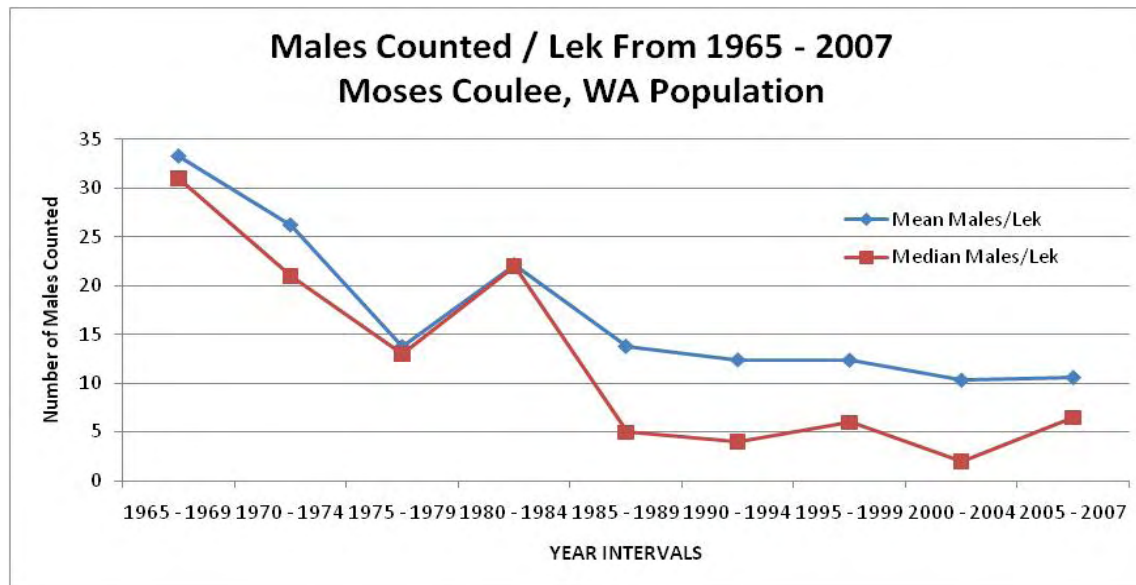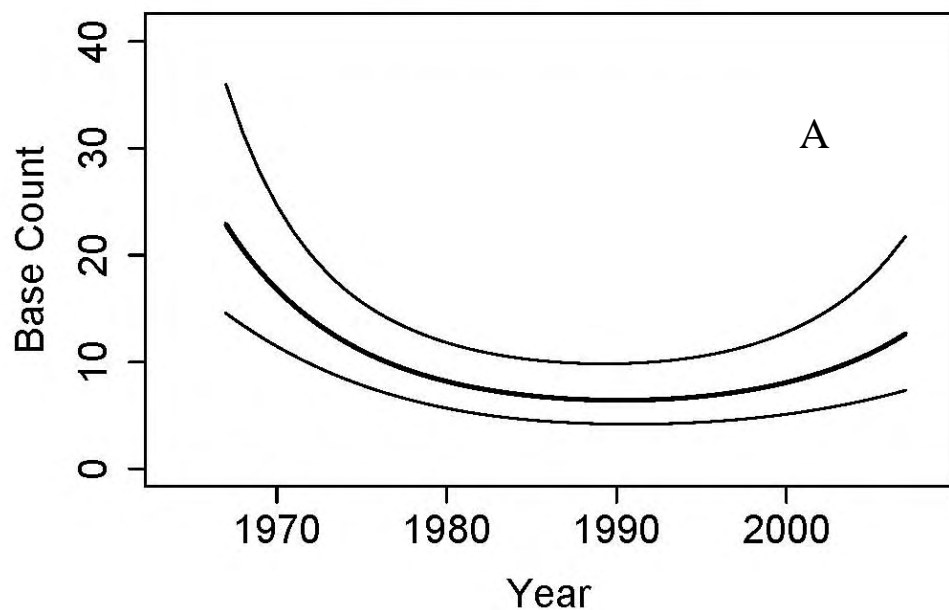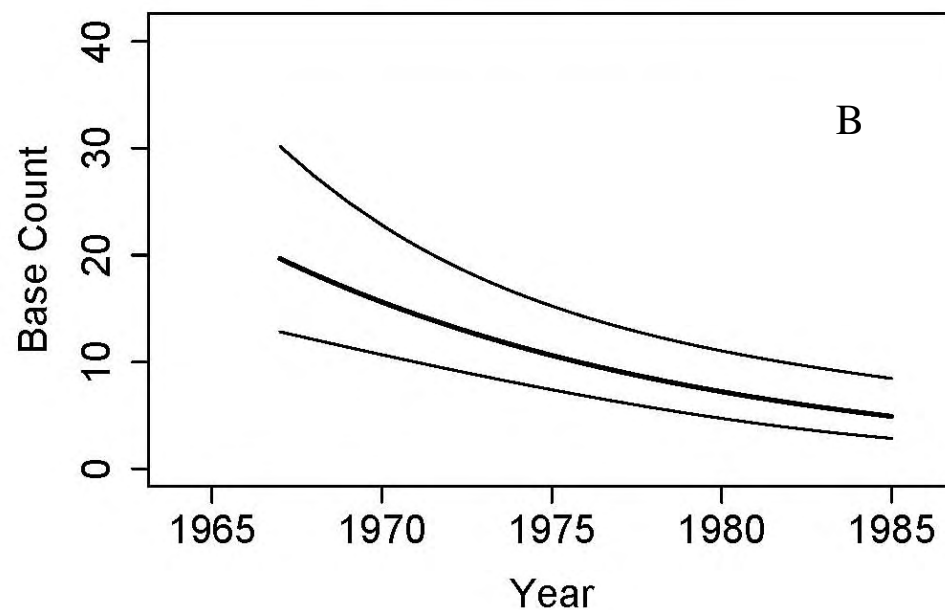

Figure D.36. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Moses Coulee, WA population.
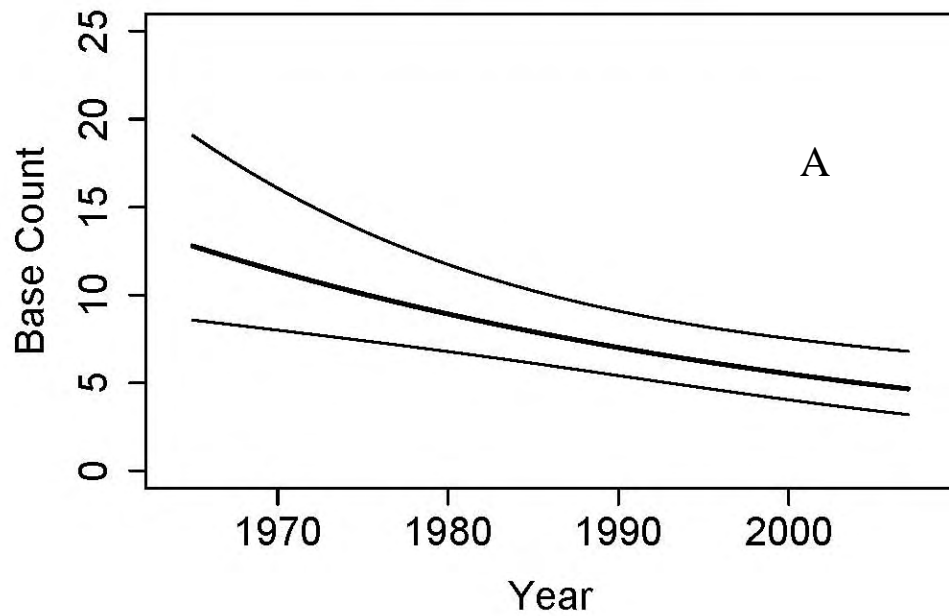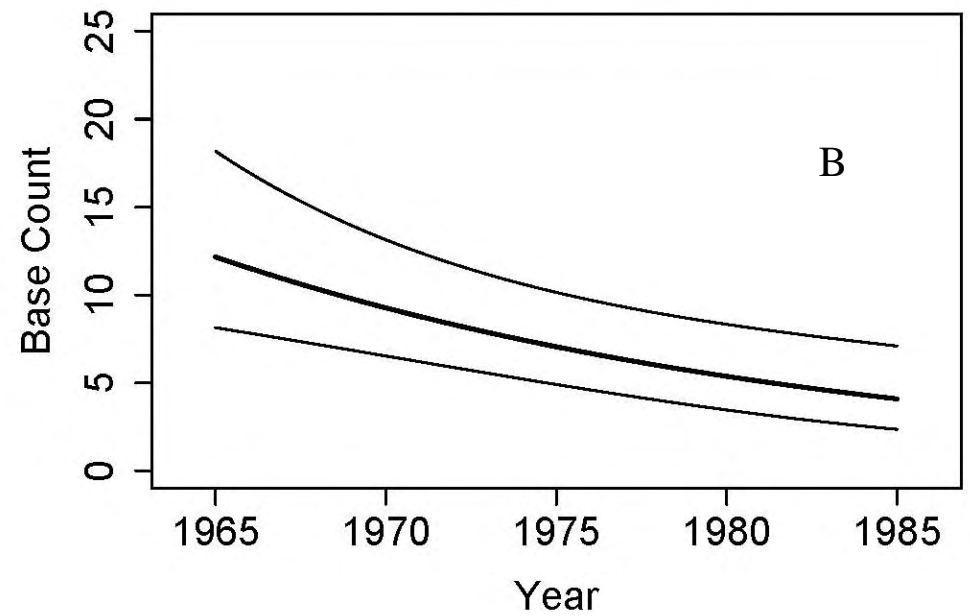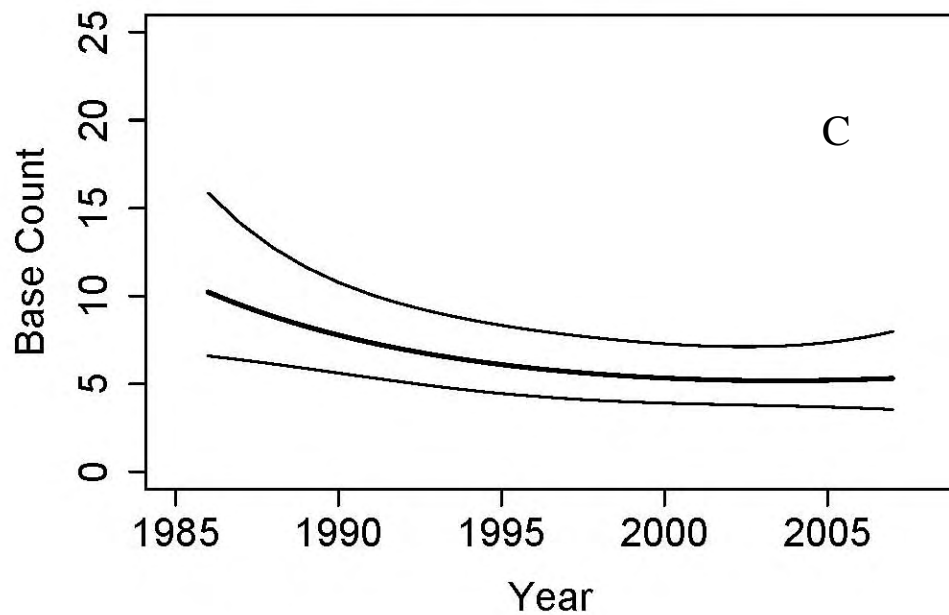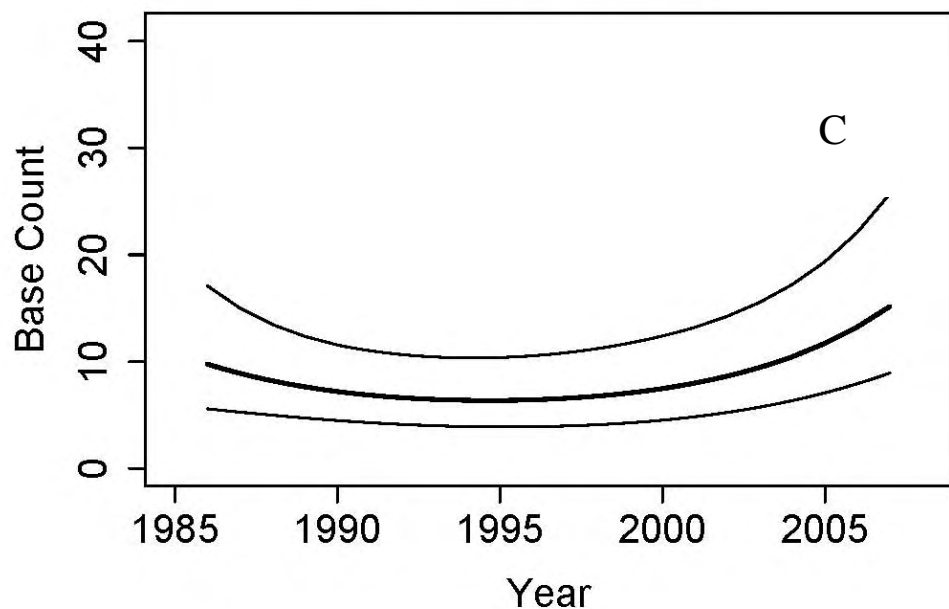
Figure D.37. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear models for 1965 – 2007 (A), and 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).
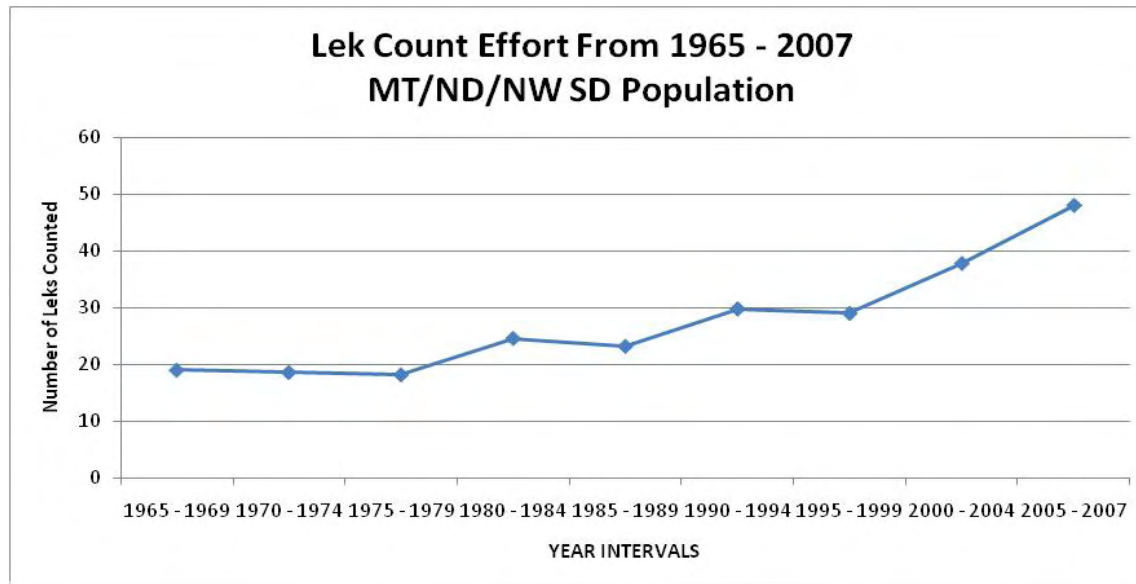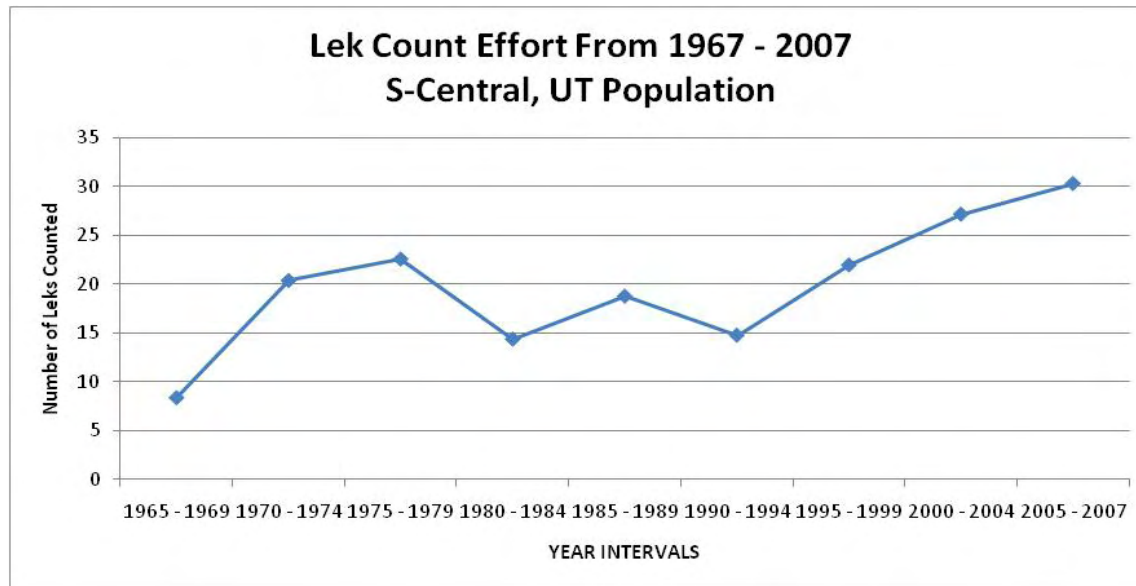
Figure D.38. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the MT/ND/NW SD population.

Figure D.39. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the MT/ND/NW SD population.

Figure D.40. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear models for 1965 – 2007 (A), and 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).

Figure D.41. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the N Mono Lake, CA population.
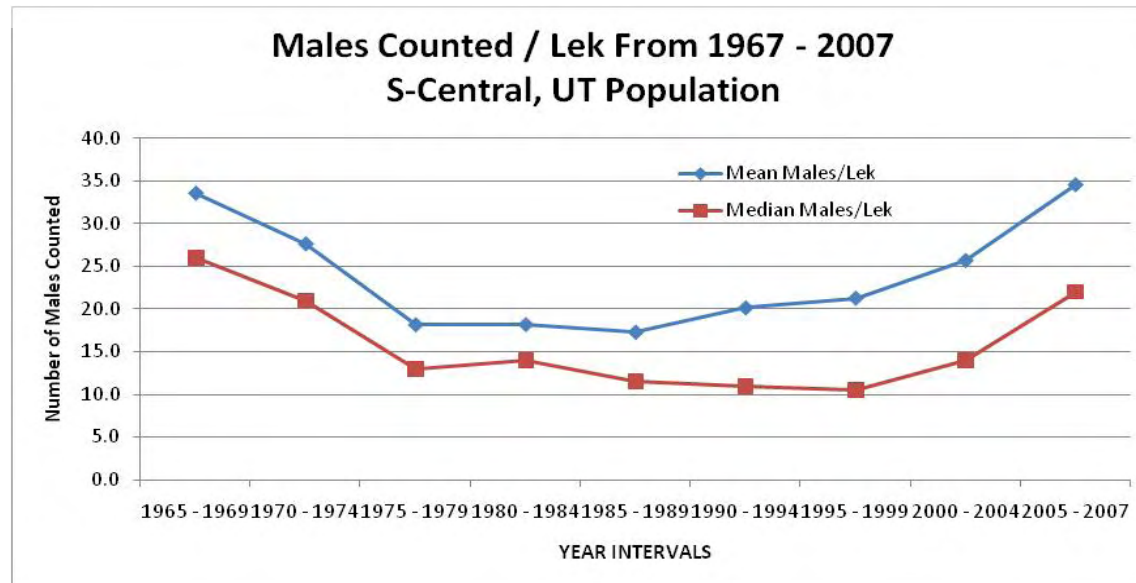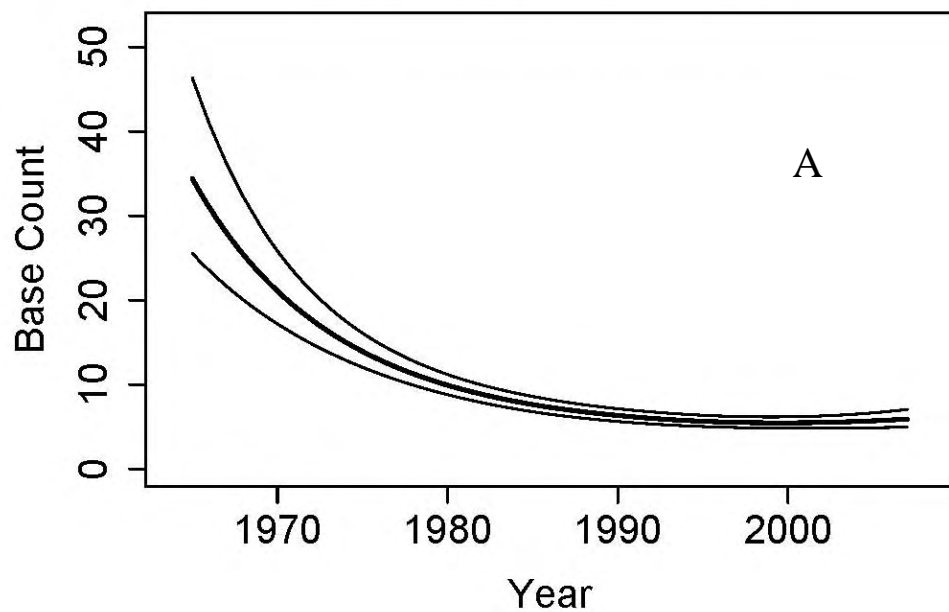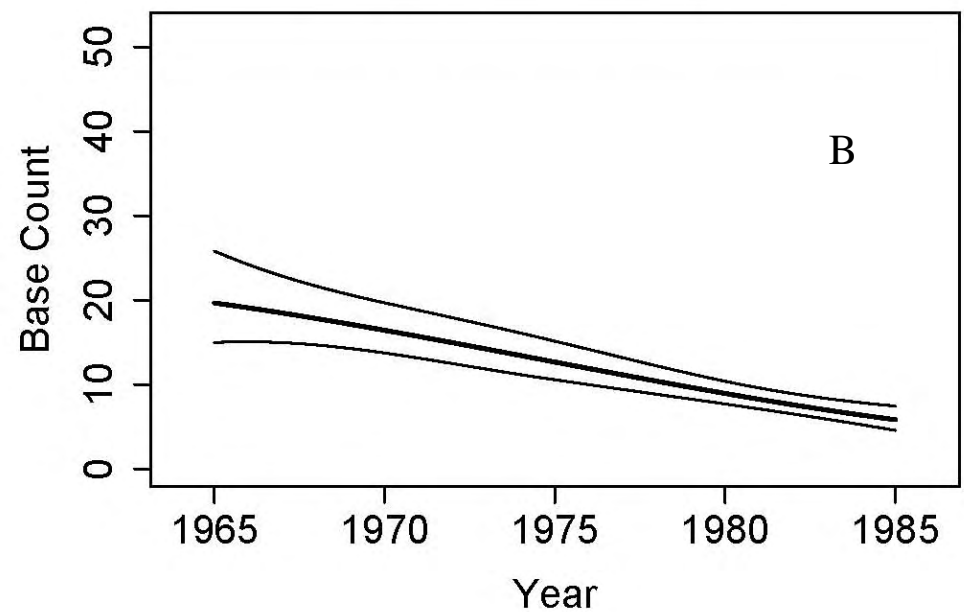

Figure D.42. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the N Mono Lake, CA population.
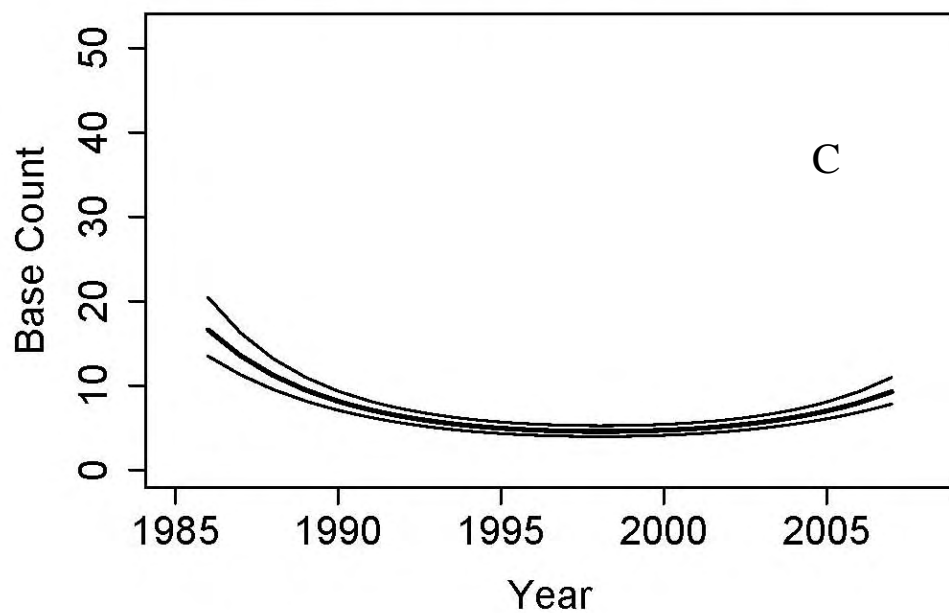
Figure D.43. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model for 1965 – 2007 (A), the linear model for 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).
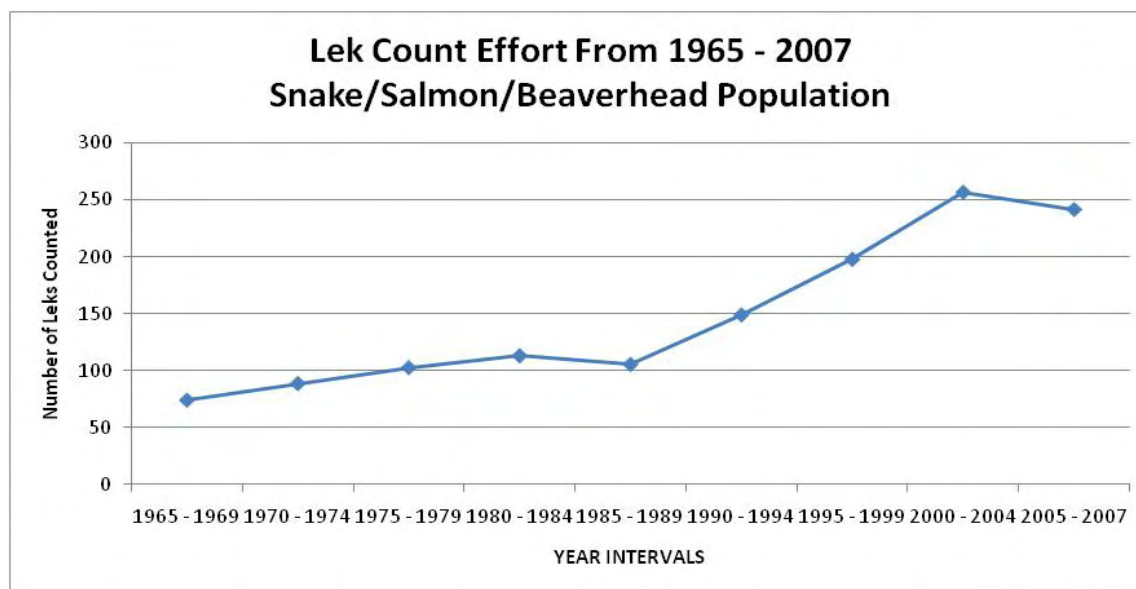
Figure D.44. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the NE Interior, UT population.

Figure D.45. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the NE Interior, UT population.

Figure D.46. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1965 – 2007 (A), and the constant models for 1965 – 1985 (B), and 1986 – 2007 (C).

Figure D.47. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Northern, MT population.
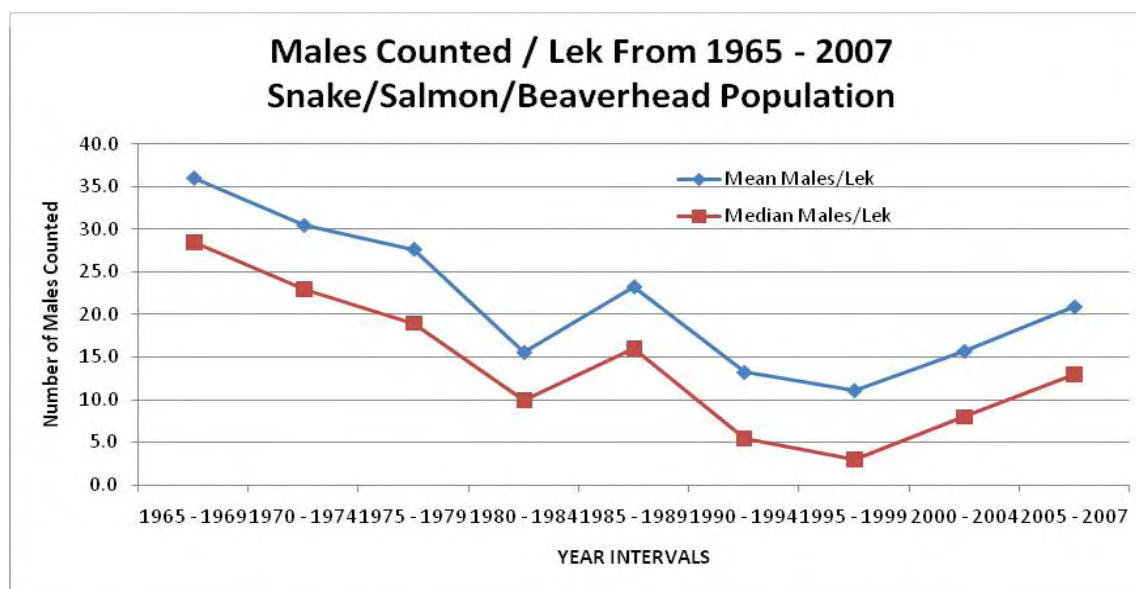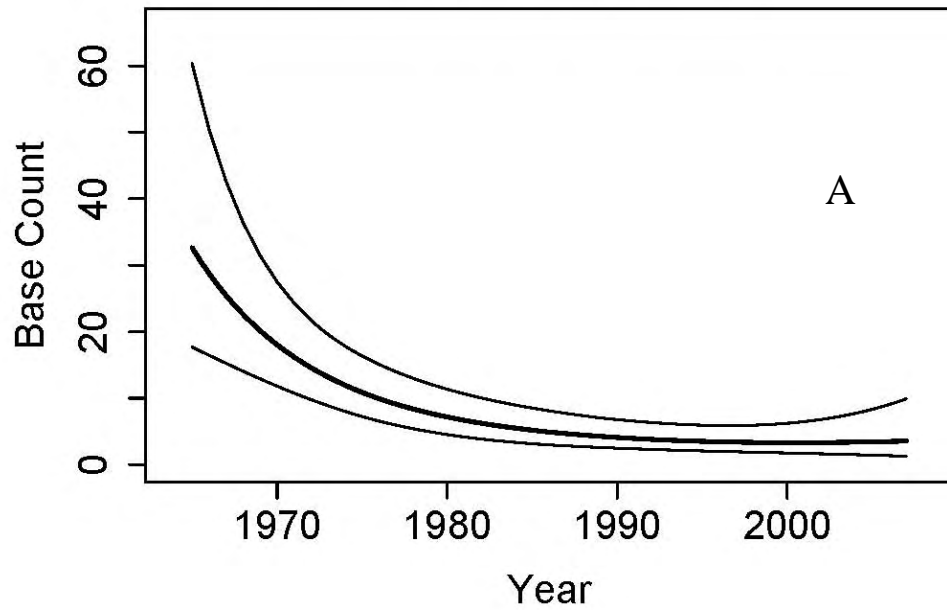

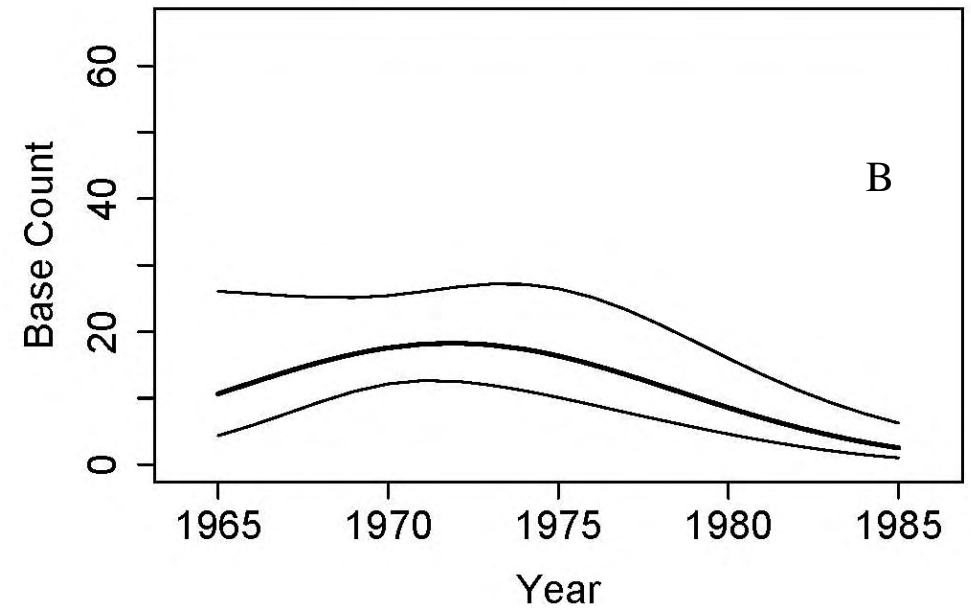Figure D.48. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Northern, MT population.

Figure D.49. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1986-2007 in the Piceance, CO population.

Figure D.50. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1986-2007 in the Piceance, CO population.

Figure D.51. The mean and median number of males counted on leks during time intervals from 1986-2007 in the Piceance, CO population.

Red Rock MT 1965−2007 (A)

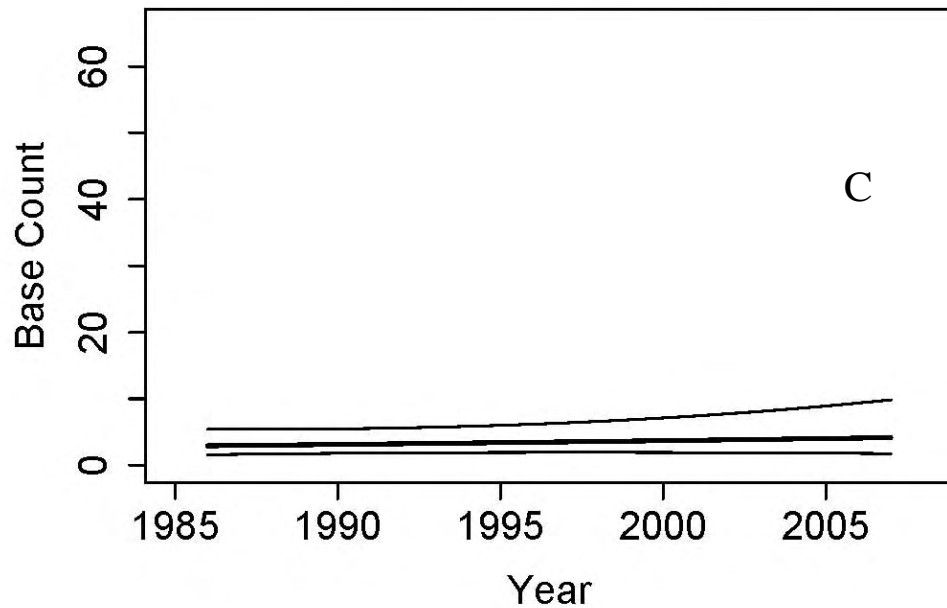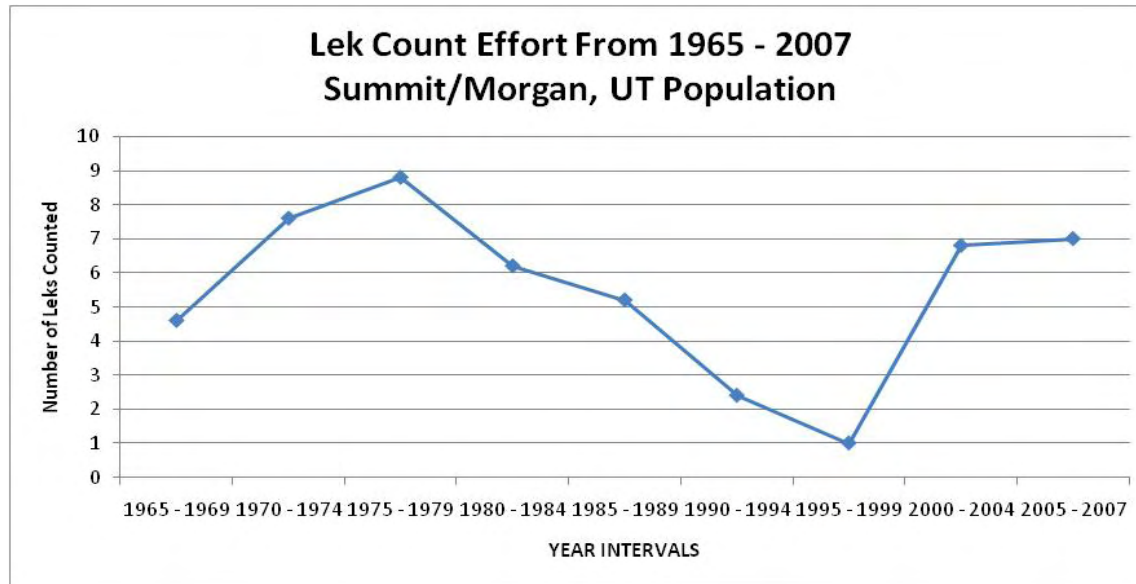**Red Rock MT 1965−1985** (B)

Red Rock MT 1986−2007 (C)

Figure D.52. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model for 1965 – 2007 (A), the linear model for 1965 – 1985 (B), and the constant model for 1986 – 2007 (C).

Figure D.53. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Red Rock, MT population.
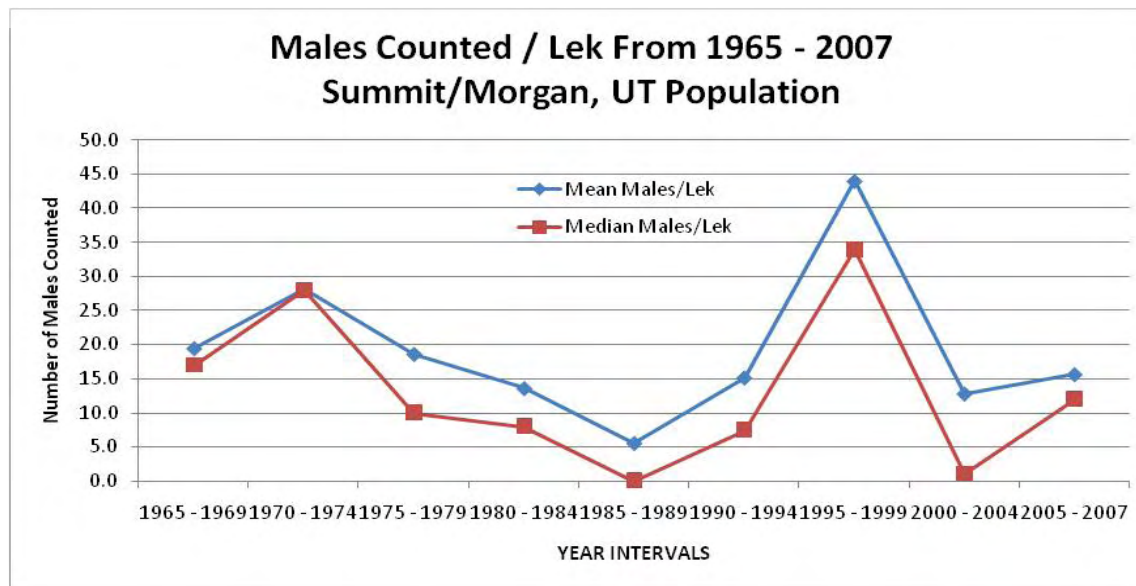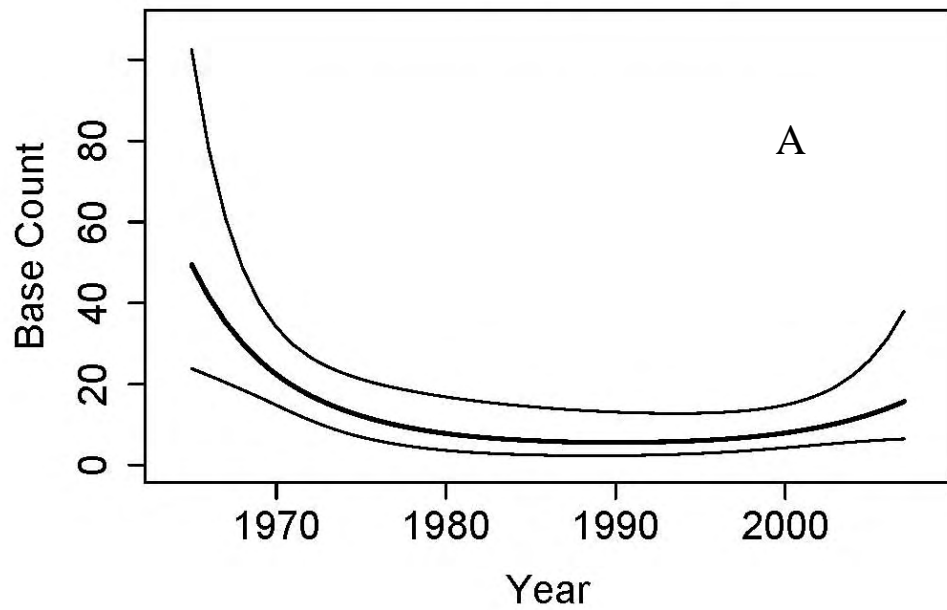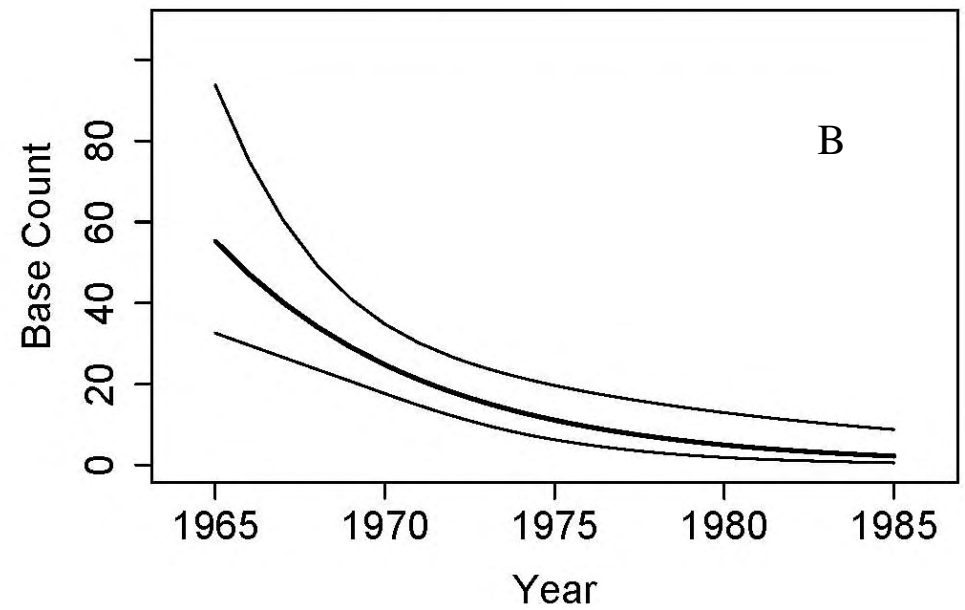

Figure D.54. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Red Rock, MT population.
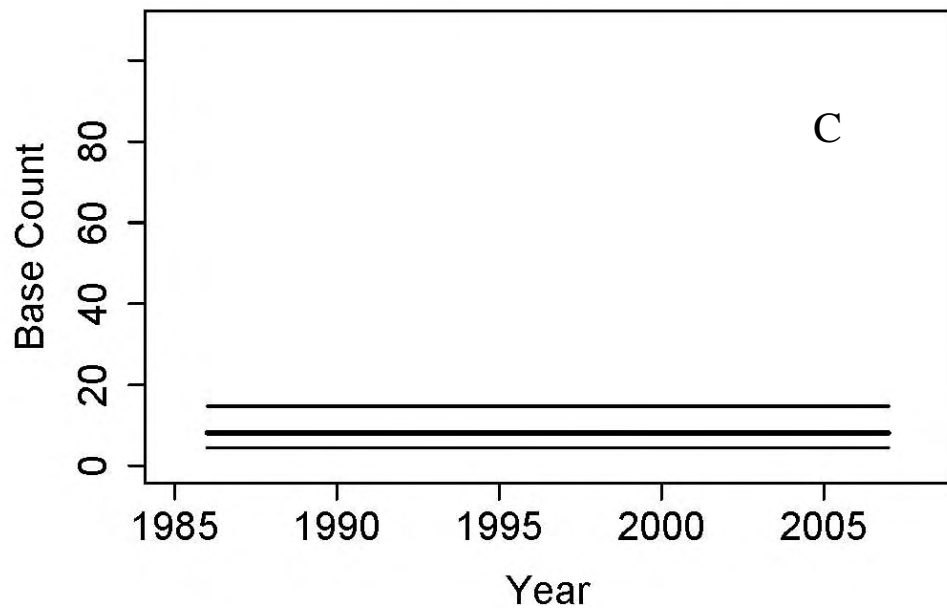
Figure D.55. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1965 – 2007 (A), the constant model for 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).
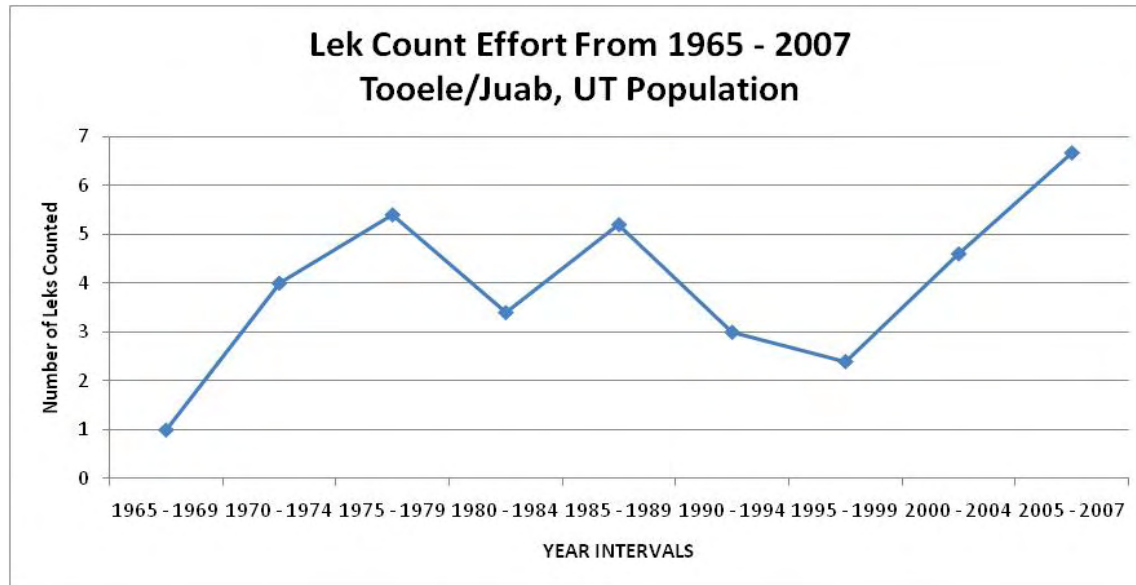
Figure D.56. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the S Mono Lake, CA population.

Figure D.57. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the S Mono Lake, CA population.

S White River UT 1986–2007

Figure D.58. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1983-2007 in the S White River, UT population.

Figure D.59. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1983-2007 in the S White River, UT population.
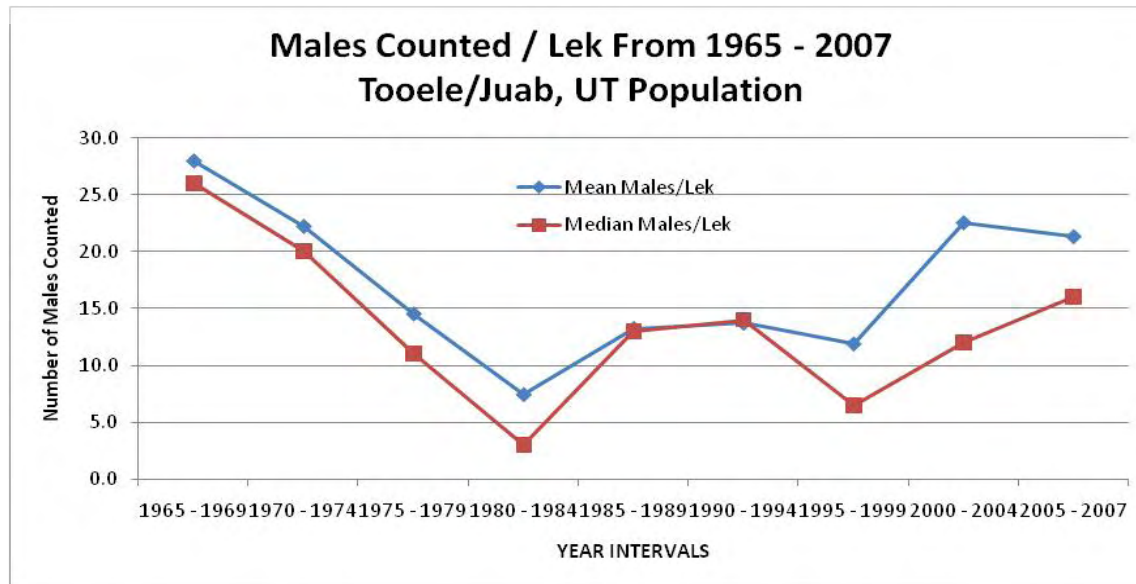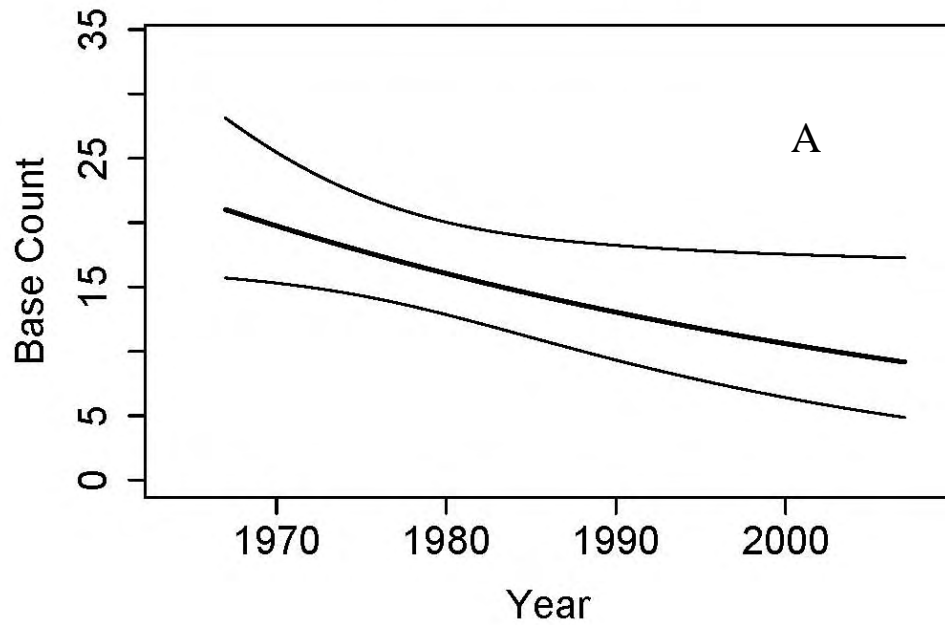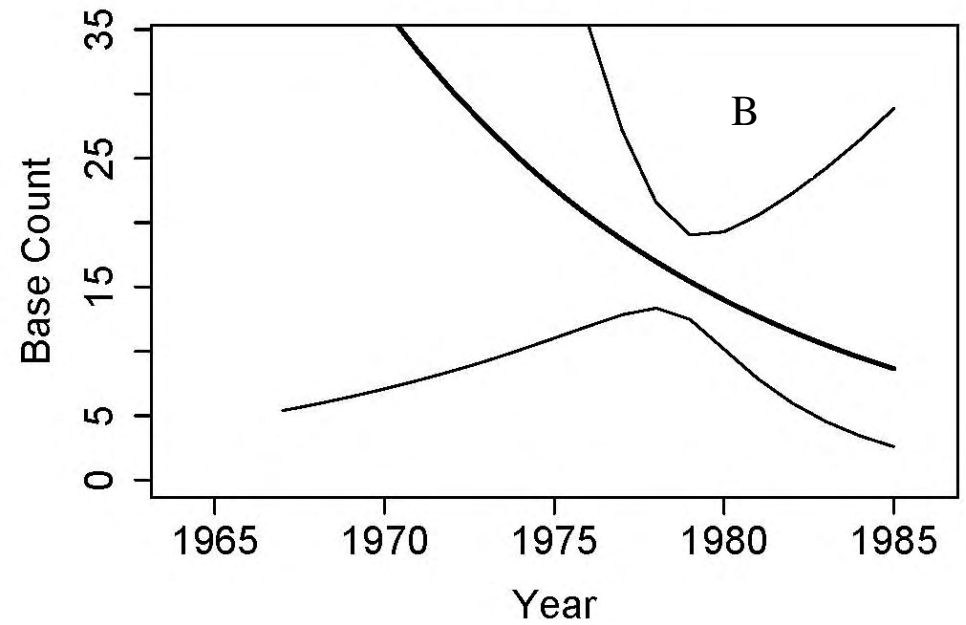

Figure D.60. The mean and median number of males counted on leks during time intervals from 1983 - 2007 in the S White River, UT population.
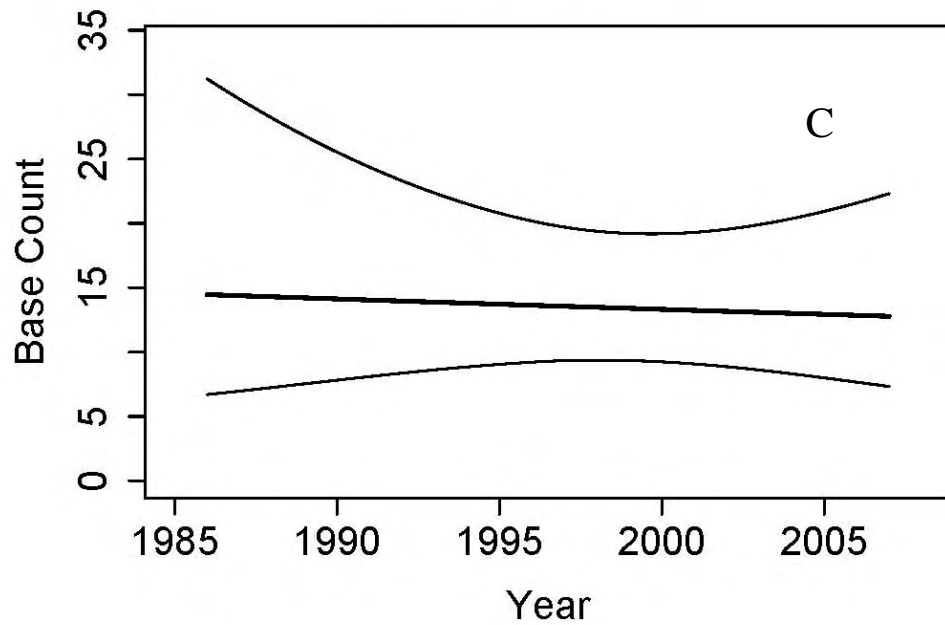
Figure D.61. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 1965 – 2007 (A), the constant model for 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).
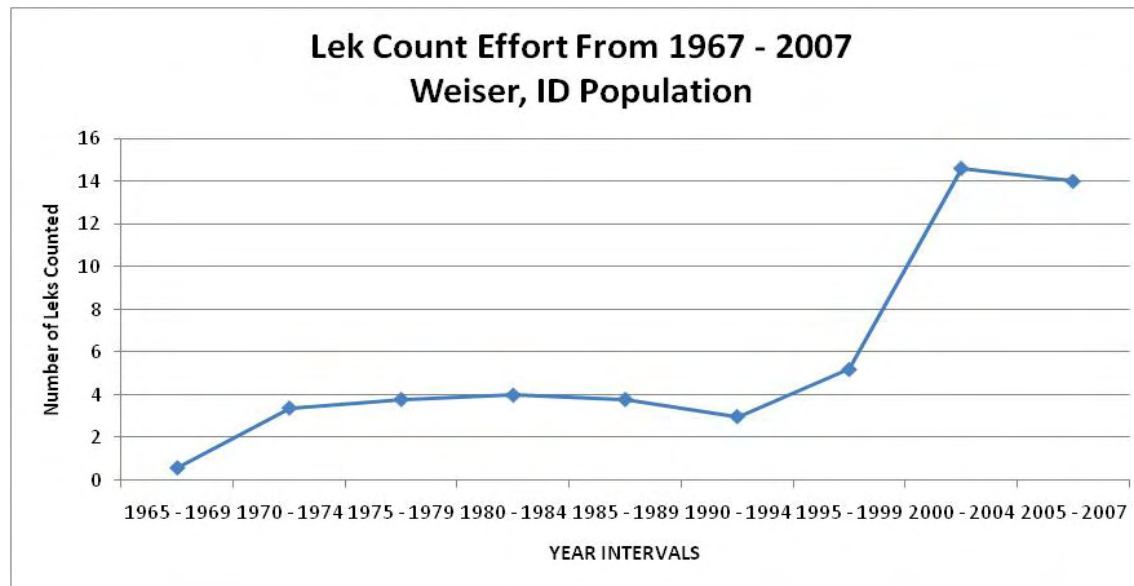
Figure D.62. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1967-2007 in the S-Central, UT population.
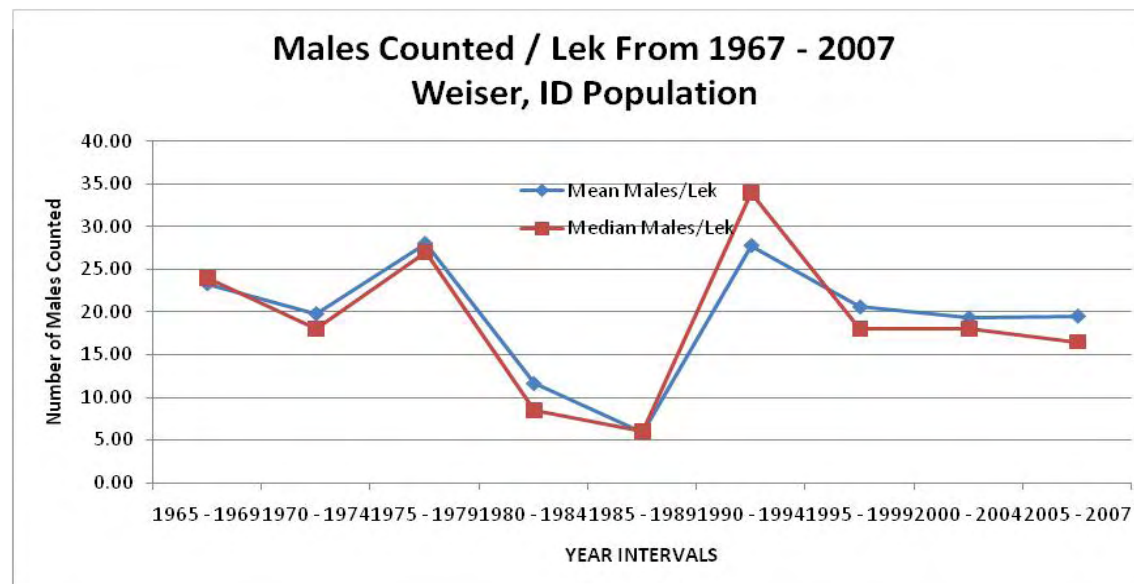

Figure D.63. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the S-Central, UT population.

Snake, Salmon and B 1965-2007

Snake, Salmon and B 1965-1985

Snake, Salmon and B 1986-2007

Figure D.64. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic models for 1965 – 2007 (A), 1965 – 1985 (B), and 1986 – 2007 (C).

Figure D.65. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Snake/Salmon/Beaverhead population.

Figure D.66. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Snake/Salmon/Beaverhead population.

Summit/Morgan UT 1965-2007

A

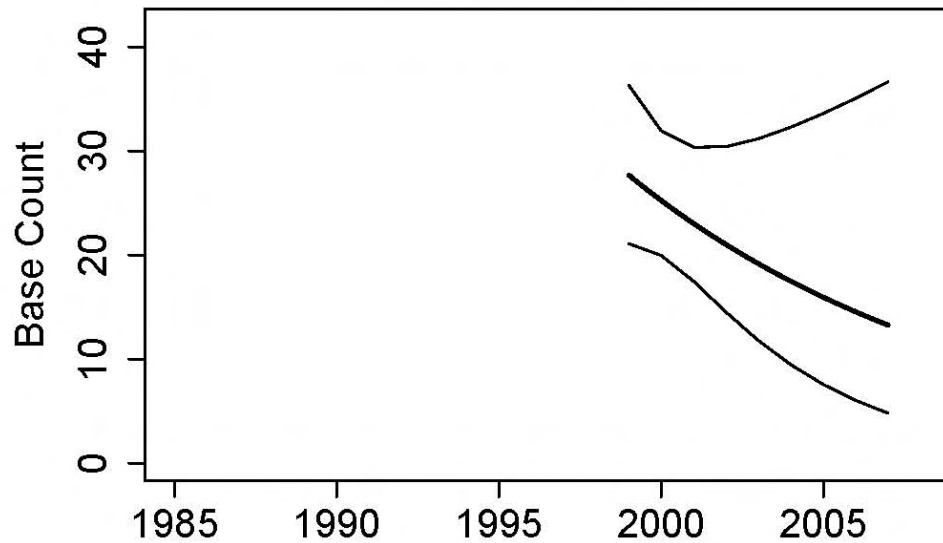## Summit/Morgan UT 1965-1985

B

Summit/Morgan UT 1986-2007

C

Figure D.67. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic models for 1965 – 2007 (A), and 1965 – 1985 (B), and the linear model for 1986 – 2007 (C).
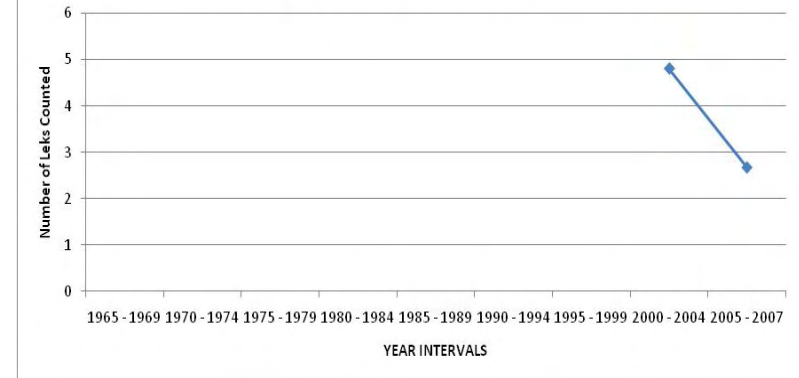
Figure D.68. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Summit/Morgan, UT population.

Figure D.69. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Summit/Morgan, UT population.

Tooele/Juab UT 1965-2007

Tooele/Juab UT 1965-1985
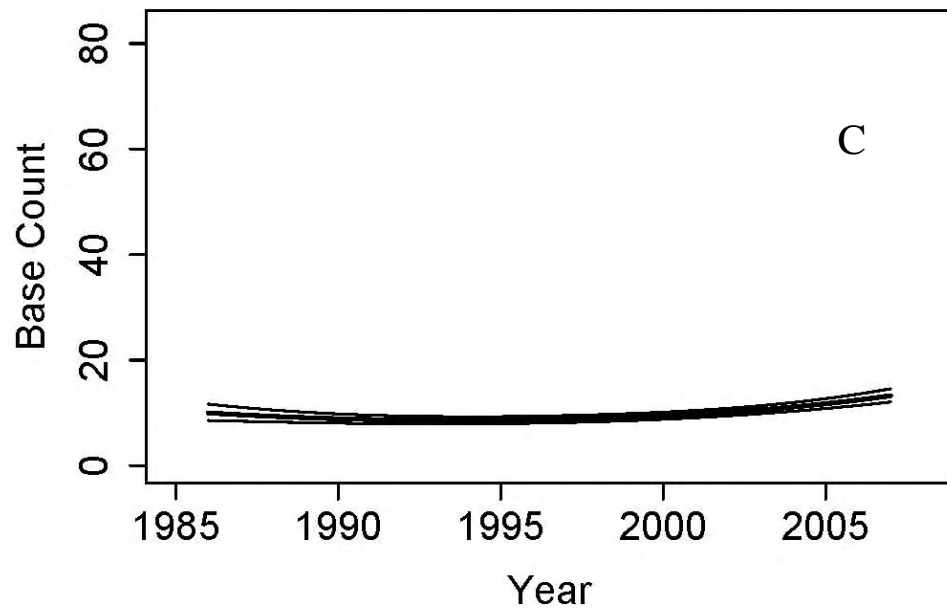
Tooele/Juab UT 1986-2007

Figure D.70. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic models for 1965 – 2007 (A), the linear model for 1965 – 1985 (B), and the constant model for 1986 – 2007 (C).

Figure D.71. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Tooele/Juab, UT population.

Figure D.72. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Tooele/Juab, UT population.

Figure D.73. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear models for 1965 – 2007 (A), 1965 – 1985 (B), and 1986 – 2007 (C).
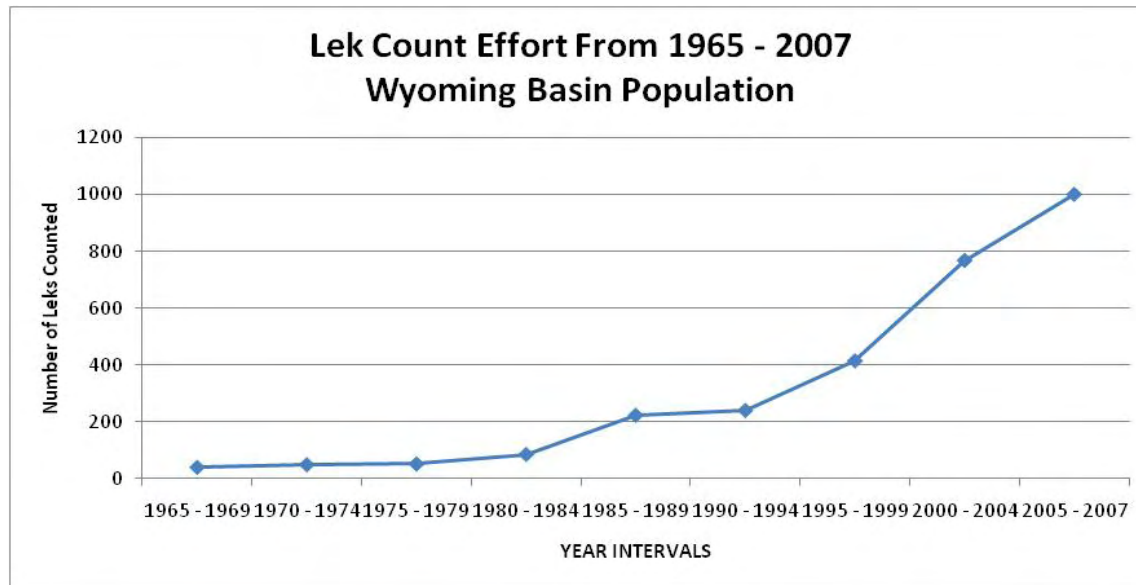
Figure D.74. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1967-2007 in the Weiser, ID population.
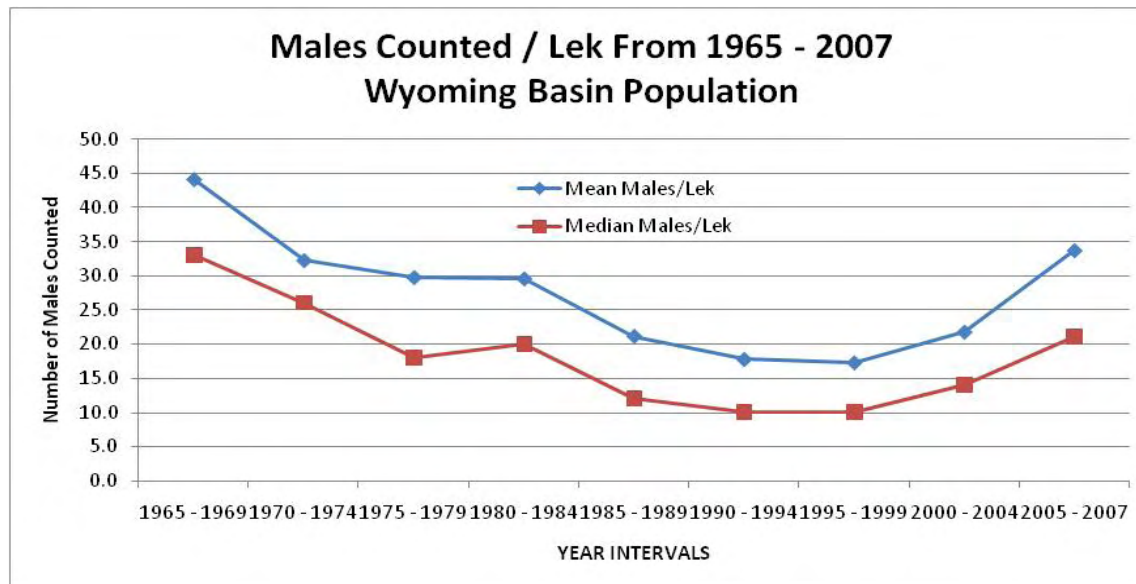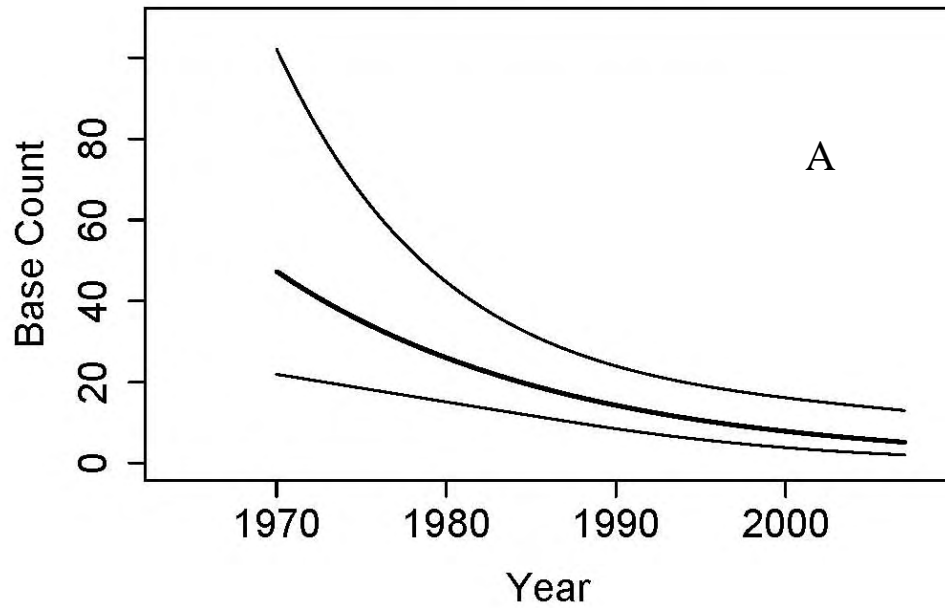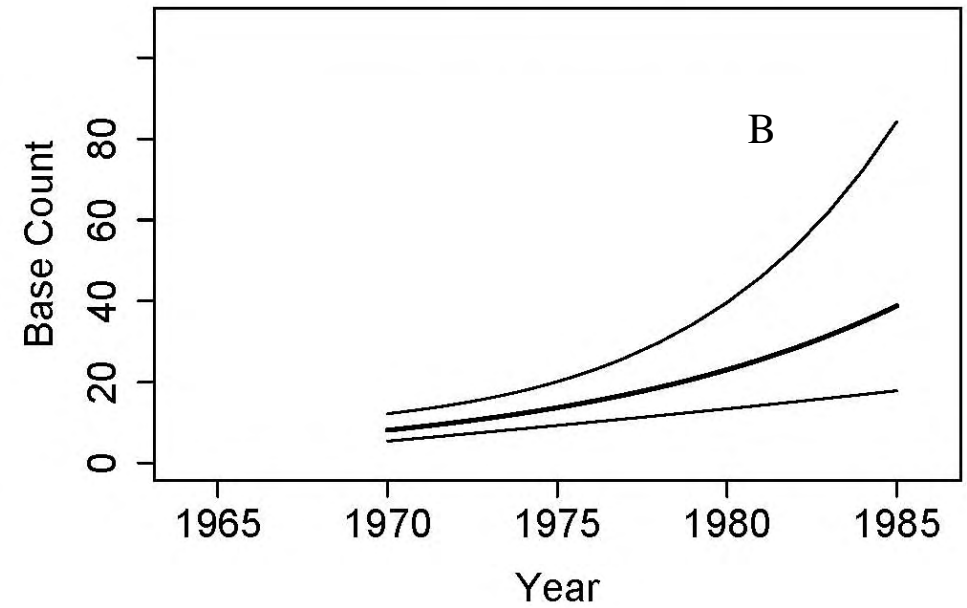

Figure D.75. The mean and median number of males counted on leks during time intervals from 1967 - 2007 in the Weiser, ID population.

Wisdom MT 1986−2007

Figure D.76. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear model for 2000-2007 in the Wisdom, MT population.

Figure D.77. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 2000-2007 in the Wisdom, MT population.
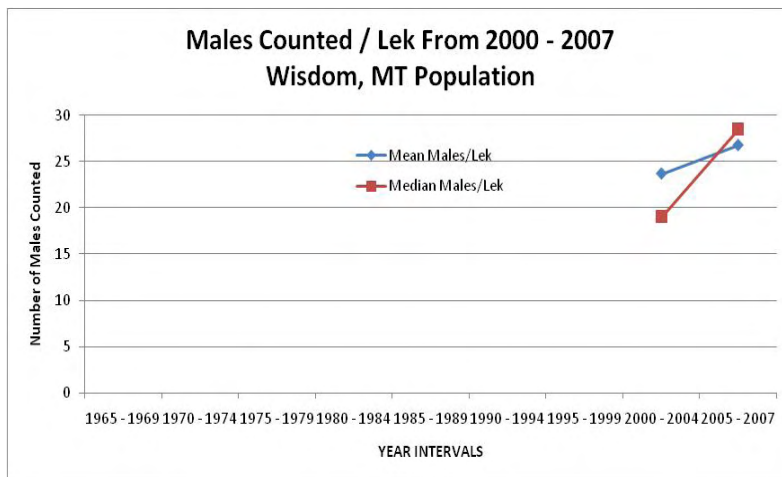
Figure D.78. The mean and median number of males counted on leks during time intervals from 2000-2007 in the Wisdom, MT population.
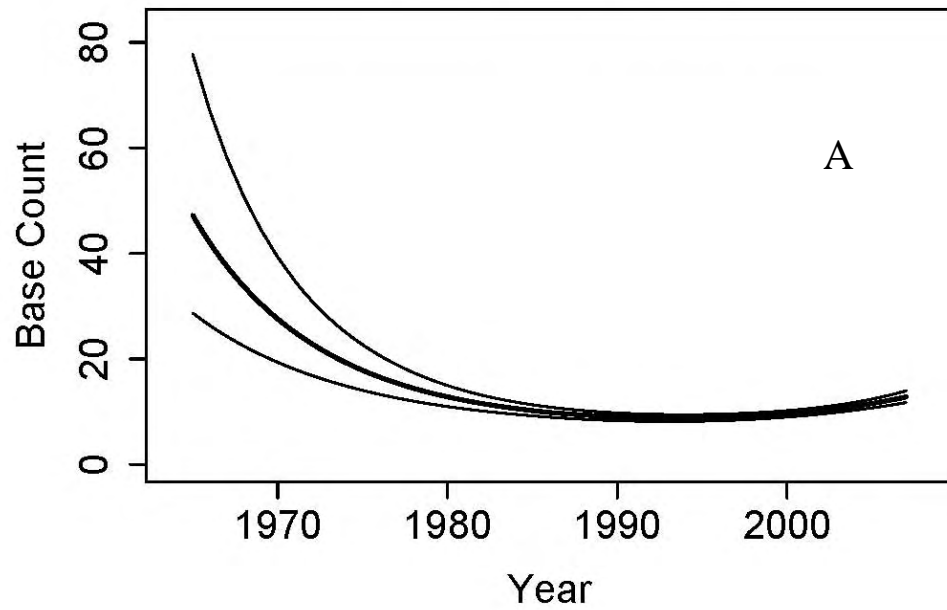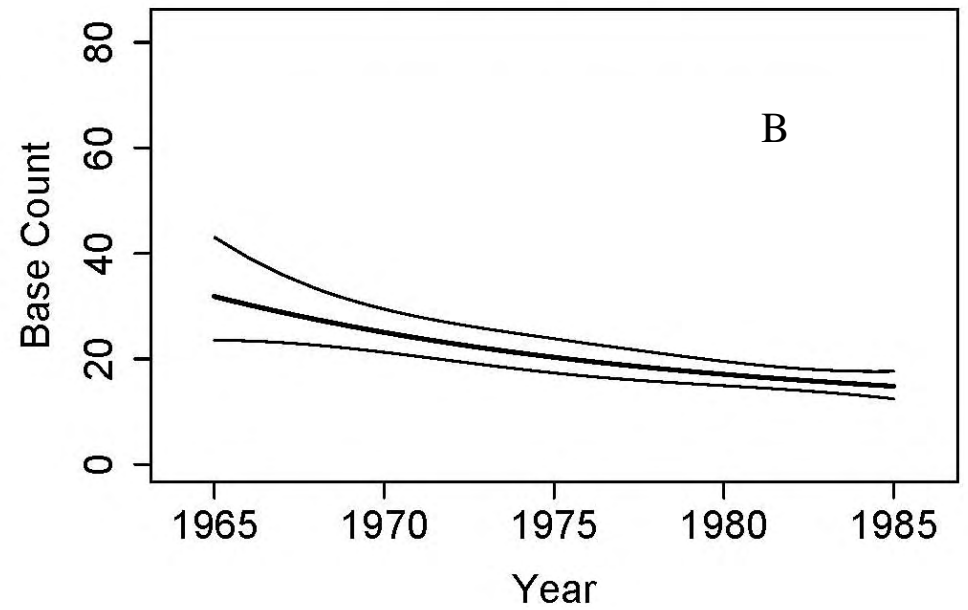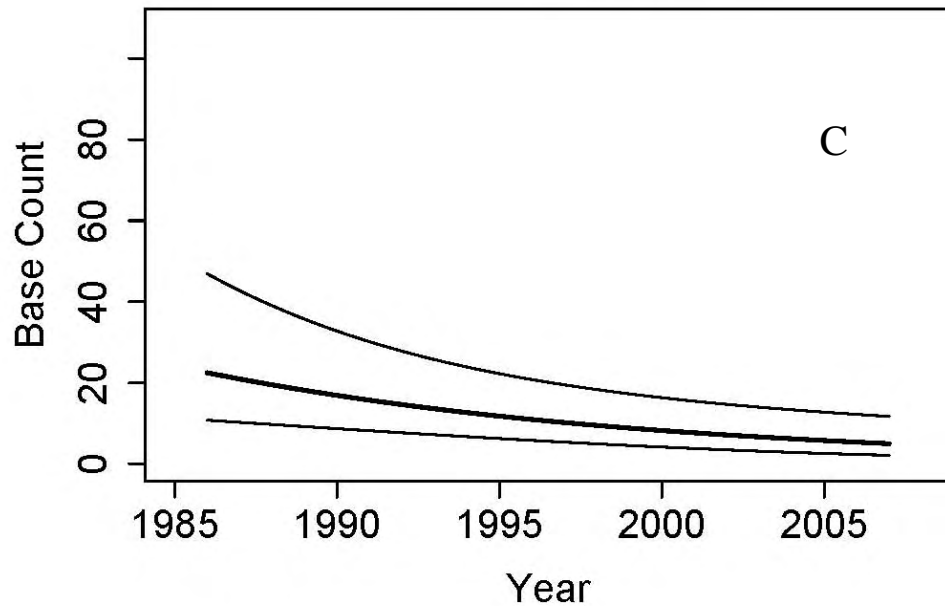
Figure D.79. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic models for 1965 – 2007 (A), 1965 – 1985 (B), and 1986 – 2007 (C).
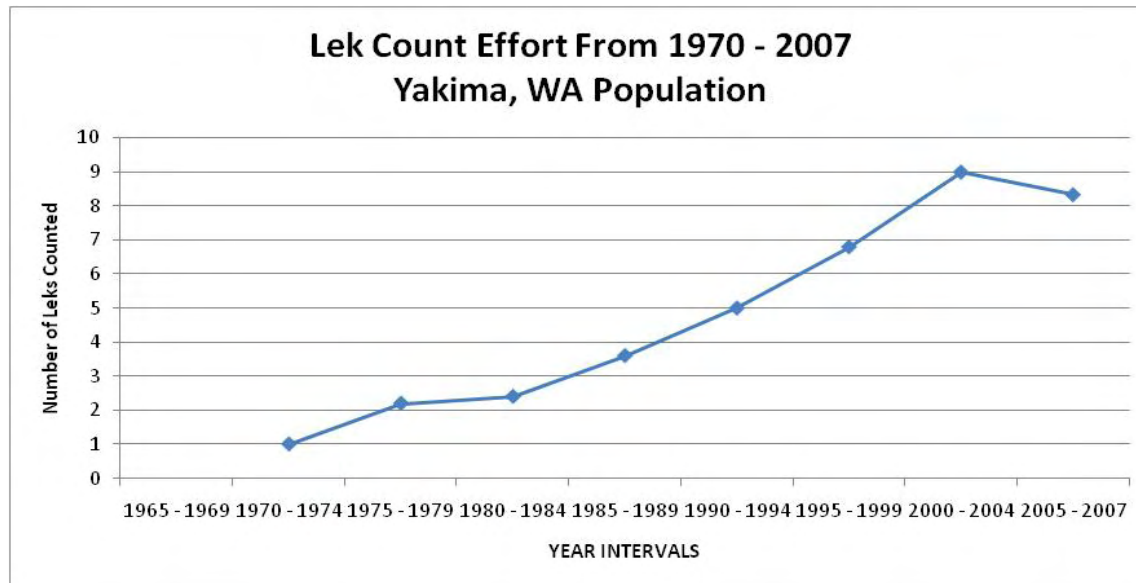
Figure D.80. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Wyoming Basin population.
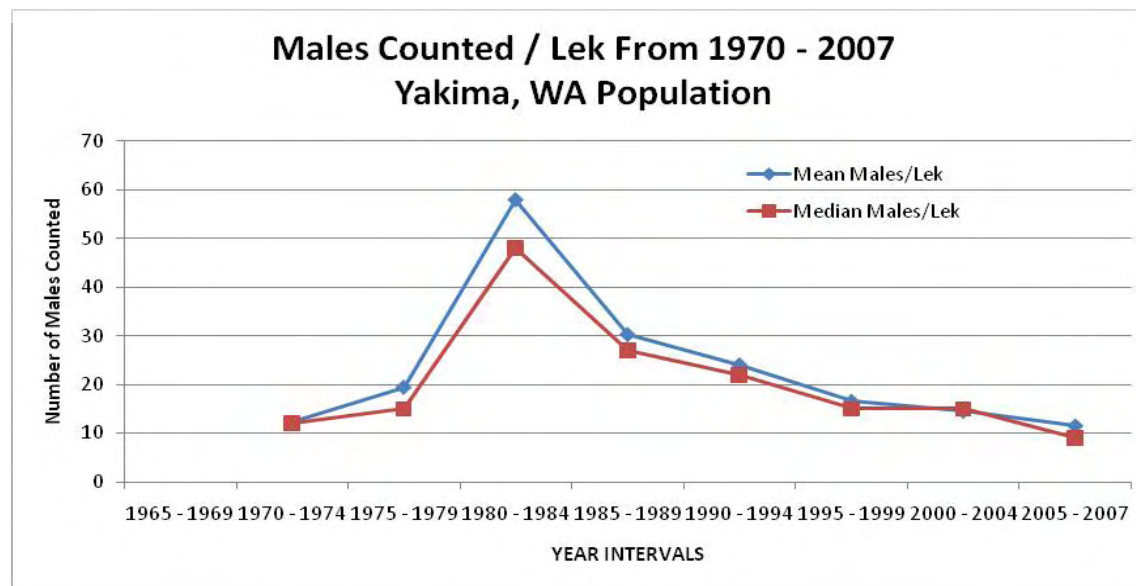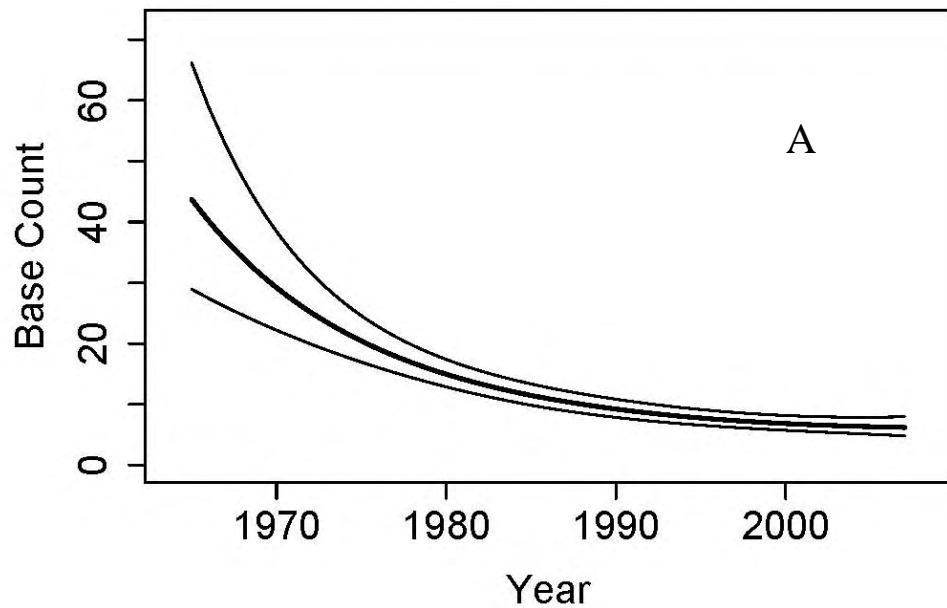

Figure D.81. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Wyoming Basin population.

Figure D.82. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the linear models for 1965 – 2007 (A), 1965 – 1985 (B), and 1986 – 2007 (C).

Figure D.83. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1970-2007 in the Yakima, WA population.
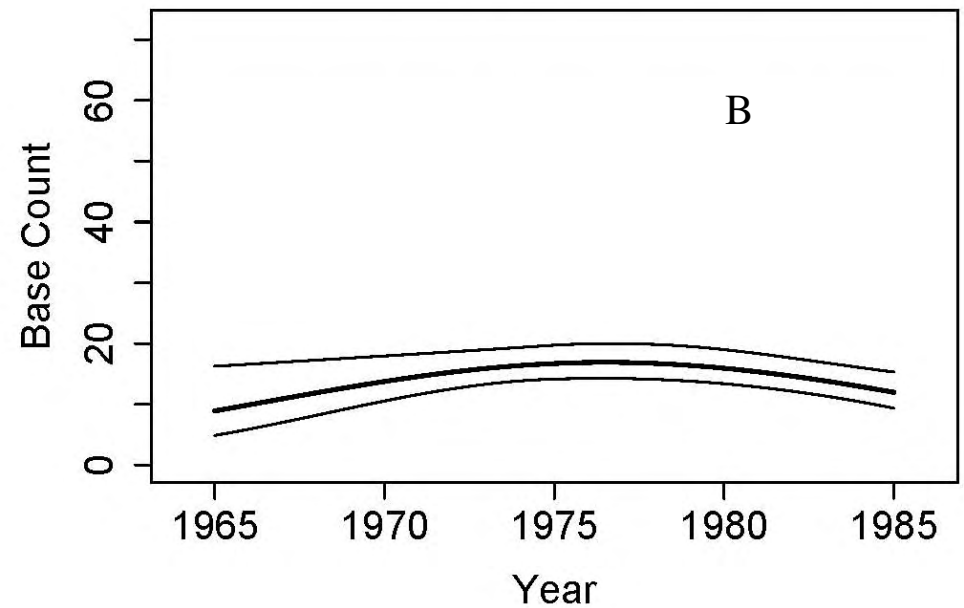

Figure D.84. The mean and median number of males counted on leks during time intervals from 1970 - 2007 in the Yakima, WA population.

Yellowstone Watershed 1965–2007

Yellowstone Watershed 1965–1985
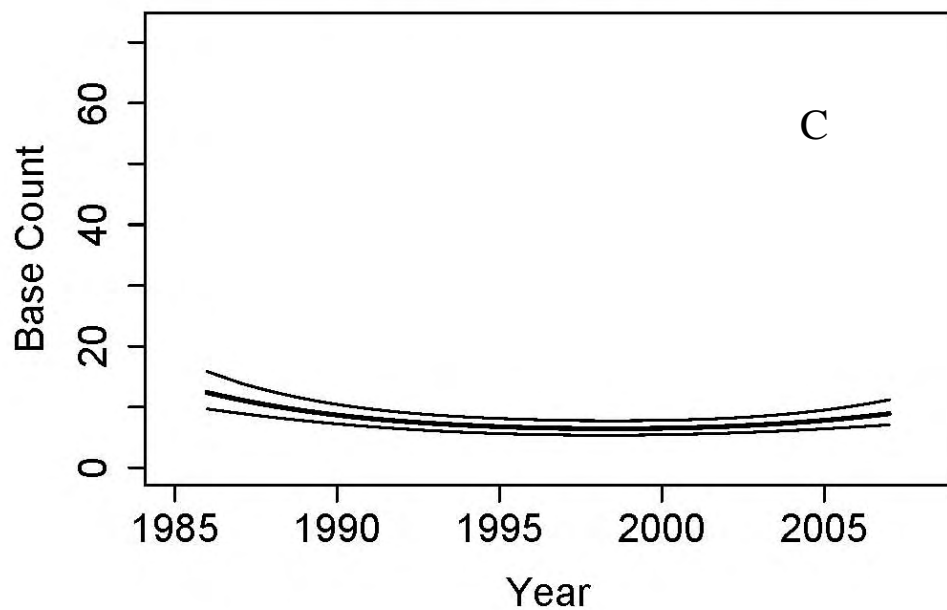
Yellowstone Watershed 1986–2007

Figure D.85. The trend and the 95% confidence intervals represent a fixed effect change in male count at the base level of the quadratic model for 1965 – 2007 (A), the linear model for 1965 – 1985 (B), and the quadratic model for 1986 – 2007 (C).
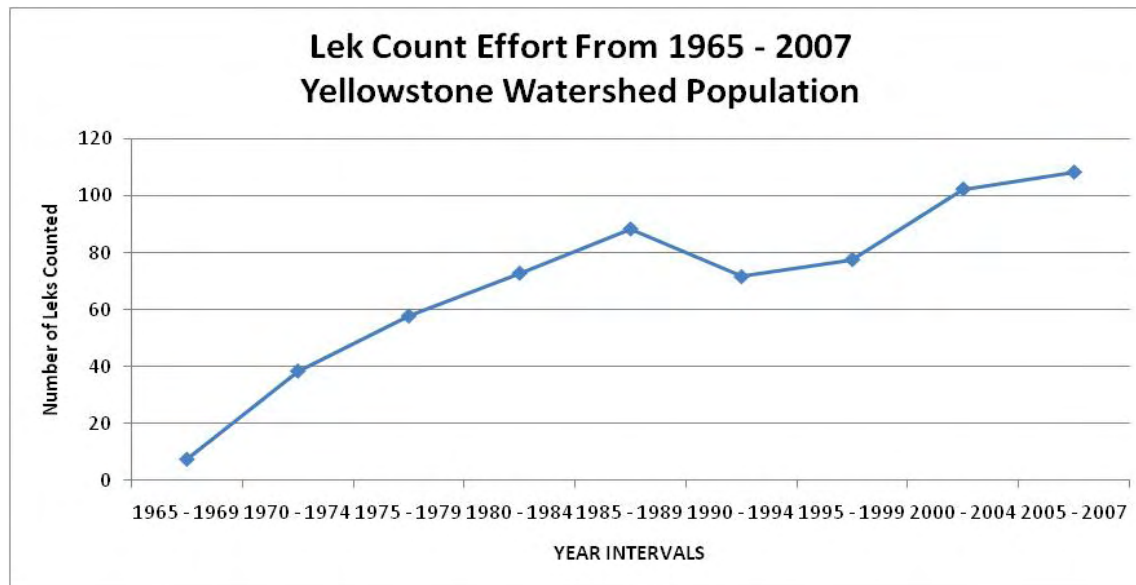
Figure D.86. The lek count effort as represented by the number of leks ground counted and included in the trend, analysis (at least 2 counts/year and at least 2 counts during sample period) in time intervals 1965-2007 in the Yellowstone Watershed population.
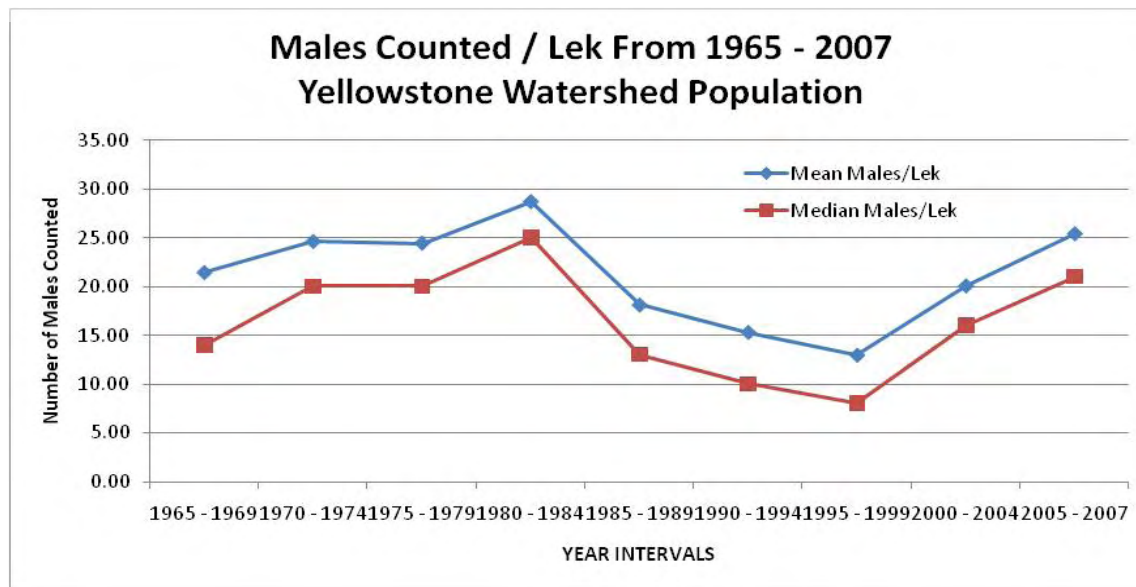

Figure D.87. The mean and median number of males counted on leks during time intervals from 1965 - 2007 in the Yellowstone Watershed population.